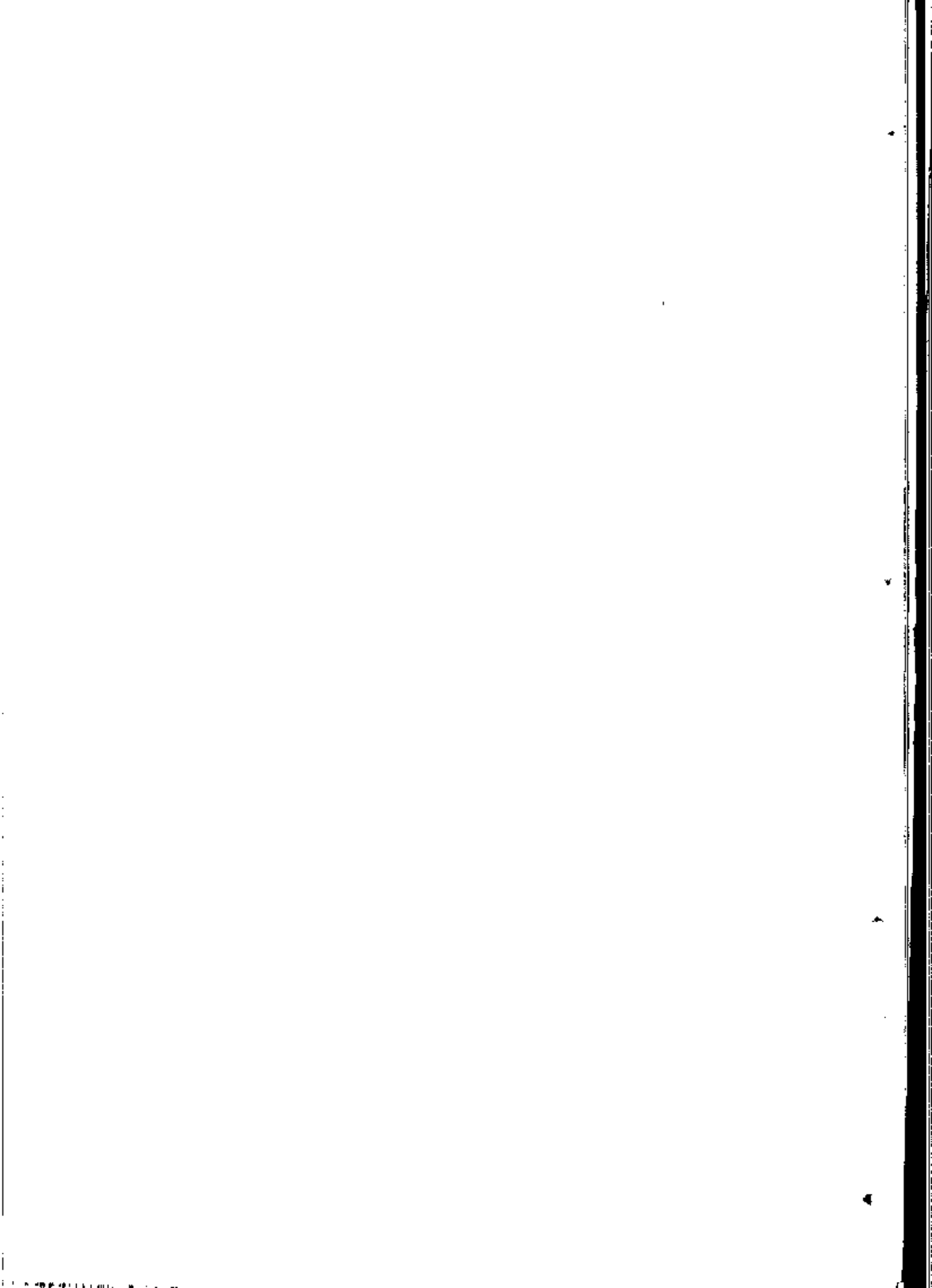


**BOOK OF SPECIFICATION
AND
CODE OF PRACTICE**

PUBLIC WORKS DEPARTMENT

SECOND EDITION



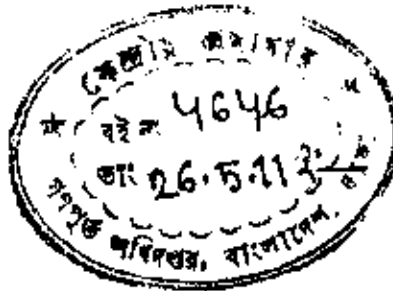
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The contents of this book are related to the construction process generally undertaken by Public Works Department which have been described hereinafter in brief theoretical form as guide lines.

As such no chapter, article, clause, sub-clause therefore, be referred to as VALID DOCUMENTS in the event of any arbitration, litigation, dispute, claim case, whatsoever secured, made or claimed by any person or persons as the case may be under any circumstances.

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PREFACE TO THE SECOND EDITION

Though writing preface to the Book of Specification and Code of Practice is very easy, the work towards publishing such a book for the Public Works Department, the principal building construction agency of the Govt. of Bangladesh is really tough. The first edition of the Book of Specification and Code of Practice was published in the year 1965. The purpose for which this book was originally written as well as its scope and limitations were stated in the preface to the first edition. In the intervening years, with fast development in the technological fields, numerous changes in specifications, requirements of construction materials, construction methodology, process of initiating projects, etc. have made a thorough revision of Book of Specification and Code of Practice imperative.

This edition of the Book of Specification and Code of Practice is the up-to-date version which covers more or less all the fields of work executed by PWD, although not expressed theoretically in detailed form. It is true that the Book of Specification and Code of Practice should have been updated long before, but due to some unavoidable circumstances in spite of all sincere efforts and goodwill, this noble task could not, however, be accomplished. At long last the second edition of the Book of Specification and Code of Practice has been published due to a long tiring, ceaseless and sincere group efforts of the committee entrusted with the task of updating the Book of Specification and Code of practice. The committee was given the task of updating the Book of Specification and Code of Practice with the latest technological developments in the field of building construction works.

In this respect I respectfully recall the name and goodself of former Chief Engineer of PWD Mr. Md. Emdadul Hoque who during his tenure initiated the process of updating the Book of Specification and Code of Practice of PWD.

As has been said before this new edition of Book of Specification and Code of Practice covers almost all the fields of construction process that is being followed in PWD which includes code of practice, material specifications, items of works, construction methodology and modus operandi.

The book has been divided in three parts namely: Part-I Codes of Practice, Part-II Specification and Description of Materials, Items and works and Part-III Specification, Description of E/M Installation works.

Part-I contains the code of practice followed in PWD. It explains the administrative part of construction process and related matters. Various executive orders, charter of duties of officers and relevant information have been included in this part. All these information have been expressed in generalised form and sample formats have been given as guide lines. All engineers specially the field engineers should follow these guide lines applying their mind, experience and skill which I hopefully expect to be exercised properly, judicially on the part of the engineers associated with construction work.

Part-II of the Book contains a brief description of construction materials and items of various works encountered in the construction process. I appreciate that all possible efforts have been made to make this part comprehensive and complete by itself packed with as many details as possible elucidating in simple and plain language.

One of the welcome features of this book is the inclusion of a new part namely Part-III relating to Electrical Installations and Maintenance specifications of works. It will not be out of place to mention here that in the past years very little importance was given to this field although E/I work covers quite a good portion of a project and is of great intrinsic importance. This part of Book of Specification and Code of Practice reflects the

detailed information about E/I works, its various components and day to day maintenance work procedure.

I hope that this book will be very much helpful to the officers and staffs of PWD. It is expected that all officers and staffs of PWD should go through the book and rigidly follow the procedure described therein. I would very much demand from the Superintending Engineers and Executive Engineers to organise training courses on the Book of Specification and Code of Practice regularly. It is my firm belief that field engineers and staff will be highly benefitted if they follow the guidelines.

Suggestions towards further improvement of the present edition will be highly appreciated and will deserve due consideration in the next edition. In spite of best efforts by the committee some printing mistakes still may remain which may be taken gracefully.

Date : 1st July, 1998

In fine I express my heartfelt appreciation to the members of committee consisting of (1) Mr. Morshed Uddin, Superintending Engineer, (2) Mr. Shawkat Ali Siddique, Superintending Engineer, (3) Mr. A.H. Md. Matiur Rahman, Superintending Engineer, (4) Mr. Md. Naseem, Superintending Engineer E/M (5) Mr. Abdullah-Al-Shafi, Executive Engineer, (6) Mr. Sayed Jahangir Kabir, Executive Engineer, (7) Mr. Md. Shah Alam, Executive Engineer, (8) Mr. Md. Joynal Abedin Bhuiyan, Sub-Divisional Engineer, (9) Mr. Md. Syed Azizul Haque, Sub-Divisional Engineer, headed by Mr. Shaikh Muzibur Rahman, Additional Chief Engineer for their efforts in publishing the Book of Specification and Code of Practice after more than three decades. It will be my pleasure and pride to see that this Book of Specification and Code of Practice would be of utmost importance to the engineers and staff of PWD in their day to day work management.



MD. SIDDIQUE ULLAH
Chief Engineer
Public Works Department
Govt. of Bangladesh
Dhaka

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PREFACE TO THE FIRST EDITION

This booklet contains the Specification and Code of Practice for a field Engineer as is necessary for practice in the actual field of construction. Though not comprehensive in its minute theoretical details, it is expected to serve all aspects in practical angles, and if carefully followed it will enable a field Engineer to execute the building works in a proper and engineering-like manner.

For an Engineer his works in profession, his knowledge in the technique of construction and his success in constructing a building is a thing of great pride for him. It is his professional religion and it is the self-satisfaction aroused in him which enables him to apply his body and mind so diligently in the arduous and difficult task of the construction. This feeling of pride and the unspeakable satisfaction make his job pleasant and make him completely forgetful of the strains of his hard work and labour. He is not only a builder of buildings but also ultimately is builder of the nation as well. The responsibility on him, however, junior he might be, even as a Work Assistant, is very great indeed as a single brick in the foundation plays a vital role in the stability of the massive structure standing over the same.

It is to be borne in mind that the knowledge of affecting economy in a construction consistent with its strength and durability really makes a man an Engineer. It should therefore be a constant struggle by an Engineer to obtain the maximum amount of durability and strength with a minimum amount of

expenditure. The question of durability and strength, however, should always have preference as the failure of structures means losing the entire economy.

Building engineering like all such branches in the technical field is a matter of strong commonsense and the application of the specialised methods and procedure in the various lines in the construction. The field engineers should therefore be very keenly alive to his own sense of examination and judgement and should rigidly follow the course of procedure and specification hereinafter described.

It is, however, pointed out that knowledge in science is very much dynamic and progressive and so also is in the case of knowledge and technique in the building construction. There should always be an effort in improving things and any suggestions for improvement will be welcomed. Without deviating much and not in a big scale the senior officers should think of better technique and more use of the indigenous materials of the country. Experimentation in the field is always a very helpful support for the research work in the laboratory.

Let us fervently hope that we strive our best to acquire knowledge and experience, apply the same in our day to day construction and not only improve in our efficiency and strength, but also contribute in the improvement of the knowledge of construction in general.

Date : 12.01.1965

(Md. Salehuddin)
Chief Engineer.

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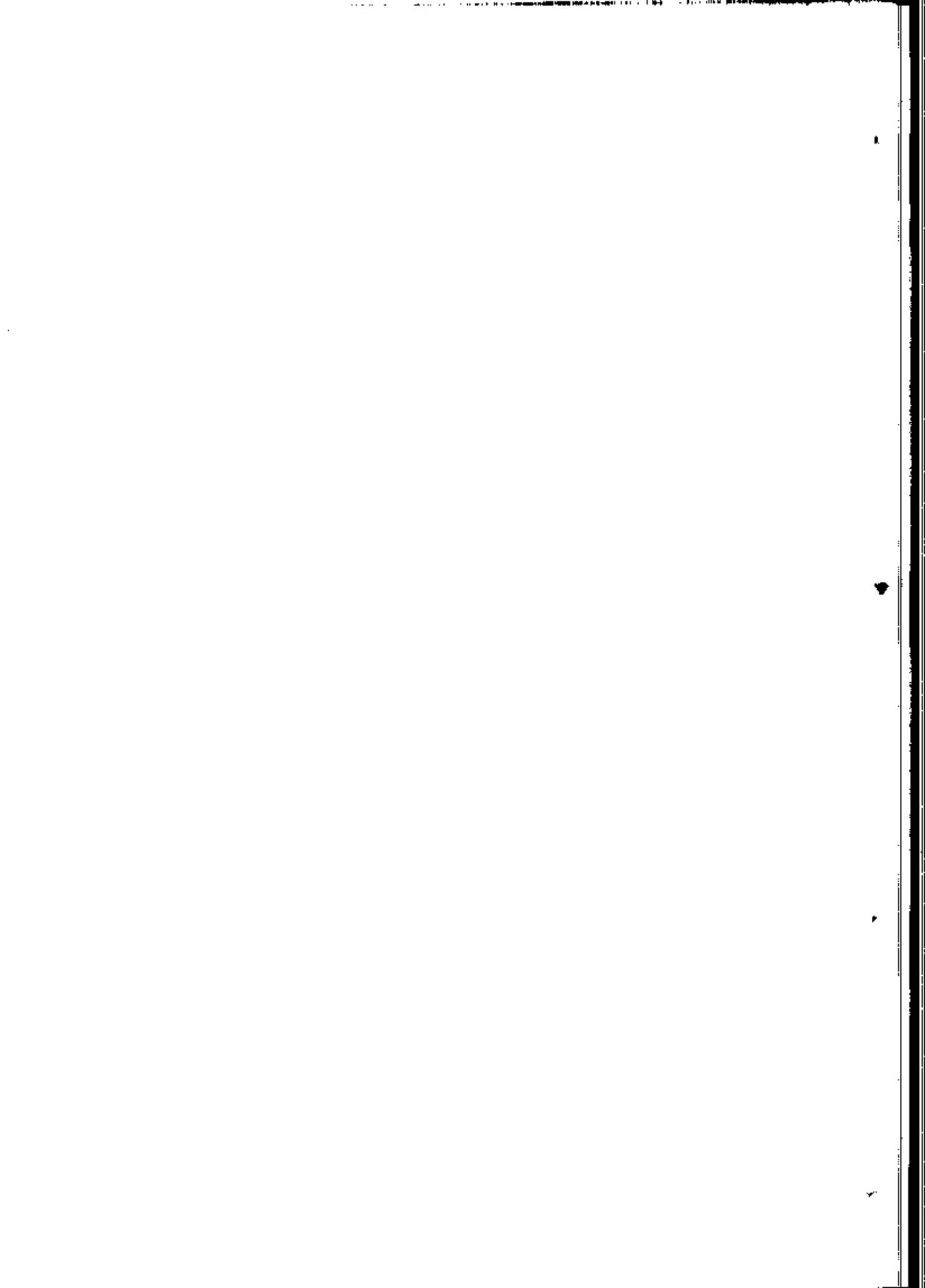
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PART-II
SPECIFICATION AND DESCRIPTION OF
MATERIALS, ITEMS AND WORKS



MATERIALS**1.1 INTRODUCTION**

All the building structures are composed of different types of materials called building materials or materials of construction. It is very essential for an Engineer or Contractor to become conversant thoroughly with these building materials. The knowledge of different types of materials, their properties and use for different purposes provides an important tool in the hands of the builders in achieving economy in materials cost.

In addition to materials economy, the correct use of materials results in better structural strength, functional efficiency and aesthetic appearance. The quality of the work depends mostly on the quality of individual building materials used in the construction work. Therefore, the knowledge about the quality of materials and proper choice of them by an Engineer will definitely lead the construction works to be durable and structurally sound with a minimum amount of expenditure. Construction materials must conform to BNBC 93. Any deviation if necessary for Structural or Architectural reasons materials must conform to ASTM/BS standards.

1.2 FIRST CLASS BRICKS

Common building brick is most extensively used material of construction. Depending upon the nature of soil from which the bricks are made, the moulded finish and the quality of burning, the bricks are classified into different categories. The classes of kiln burnt bricks used in the works of Public Works Department are : First class bricks, First class bats, Picked jhama bricks, Jhama bricks and Jhama bats.

Specifications of First class bricks according to BDS 208 are as follows :

- i) Bricks shall be of uniform colour, shape and size having sharp square sides and edges and parallel faces.
- ii) Bricks shall be sound, hard and well burnt homogeneous in texture and free from flaws and cracks.
- iii) Bricks shall emit a clear metallic sound when struck with a small hammer or another brick.
- iv) A First class brick should not absorb more than 1/6th of its dry weight when immersed in water for 24 hours.
- v) A First class brick should not break when struck against another brick or when dropped at T-position on the hard ground from a height of 3 to 4 ft.
- vi) Standard dimensions of bricks shall be 240mmx115mmx70mm
- vii) Allowable variations in dimensions shall be :

- a) In length not more than 6mm.
- b) In breadth not more than 5mm
- c) In height not more than 1.5mm
- vi) Unit weight of bricks shall be 1100kg/cum
- vii) Compressive strength of brick shall be for
 - a) Halved bricks, mean of 12 bricks : 28 MPa(4000psi)
 - b) Minimum for individual bricks : 21.1 MPa(3000psi)
- x) Range of efflorescence for a first class brick shall be slight to nil.

1.3 REINFORCING STEEL

1.3.1 M.S. Plain Bar BDS - standard

Mild steel round bars conforming to BS 1313 : 91 A-36-91/BNBC 5.3.3 BS 4449 or ASTM A-36 or equivalent requirements as stated below shall be used as reinforcing steel.

- Yield strength, f_y : Not less than 275 MN/sq.m (40,000psi)
- Ultimate tensile strength : Not less than 400 MN/Sq.m (60,000psi)
- Percentage elongation (50mm gauge) : Minimum 23%
- Reinforcing steel must be of standard dimensions and free from any defects such as cracks, surface flaws, laminations, jagged and imperfect edges.
- all reinforcement shall be free from loose rust and coats or paint oil, mud or other materials which may destroy or reduce bond.

1.3.2 Deformed bars. BNBC 5.32 BDS 1313

Tensile strength :

Grade	Nominal Size	Tensile strength N/mm ²	Minim. elongation gauge length (Lo)% ³
250	all sizes	250	22
275	"	275	20
350	"	350	14
400	"	400	12
500	"	500	8

$L_o = 5\phi$ where L_o is the gauge length of the test piece, ϕ is the nominal dia of the test piece.

Deformation requirement and Bond classification shall conform of BDS 1313:91

1.4 TIMBER FOR DOOR AND WINDOW BNBC 2.10.1

All locally available good quality timber except mango having ultimate compressive strength parallel to the grain, not less than 17 (2500 Psi) and bending stress not less than 24.1 (3500 Psi) shall be used as door and window frames and shutters.

— Timber shall be well seasoned, dry and straight grained, free from knots and other defects affecting its appearance, strength and durability. It must conform to BNBC 6.11.1

For Sawn timber BNBC Table 6.11.2, 6.11.3, 6.11.4, 6.11.5

For tolerance BNBC 11.4.4.2

For grading BNBC 11.4.5.1, 11.4, 5.2

For suitability BNBC 11.4.6

For permissible stress BNBC 11.5.1, 11.5.2

1.5 CEMENT

Specifications of Portland cement BS 12 or ASTM C-150 BDS 232 1993 BDS 612 BNBC 2.4.7, 5.2.1 BDS 232 or its equivalent must conform to the following requirements.

- Water for normal consistency : 26% - 33%
- Fineness : 280 Sq.m/Kg. (By Air permeability method)
- a) Initial setting time : Not less than 45 mins.
- b) Final setting time : Not more than 8 hours
- Compressive strength (standard mortar Cube 50mm size)
 - a) 3 days = 13 MN/sq.m. (1800 Psi)
 - b) 7 days = 19 MN/Sq.m. (2800 Psi)
 - c) 28 days = 29 MN/Sq.m. (4000 Psi)
- Tensile strength (standard mortar briquette)
 - a) 3 days = 1.00 MN/Sq.m. (150 Psi)
 - b) 7 days = 1.9 MN/Sq.m. (275 Psi)
 - c) 28 days = 2.4 MN/Sq.m. (360 Psi)

1.6 SAND

Should conform to the following requirements and BDS 243 : 1963, ASTM C 40-92, C 87-83 (1990)

- Organic materials content shall not exceed 5%
- Silt and other fine materials content shall not exceed 6%
- the grading shall be within the range

Sieves	No. 8	No. 16	No. 30	No. 50	No. 100
% Passing	100-92	74-90	45-74	30-50	0-6

- the fineness modulus of sand shall be :

Type of work.	Minm F.M.
Concrete	1.8
Mortar	1.5
Filling sand	0.8

7 AGGREGATE (COARSE AGGREGATE)

7.1 Khoa (Brick chips)

Khoa made from bricks shall conform to the following requirements :
It must be made of first class and picked jhama bricks.

- Nominal size : The grading shall be within the following limits (for 19mm down graded).

Size/sieve.	19mm	9mm	No. 4	No. 8
% Passing	95-100	25-55	0-10	0-5

Appearance : shall be completely non plastic and shall be completely free from all organic and deleterious materials.

- Unit weight : unit weight shall not be less than 1100 kg/cu.m.
- Water absorption : as a percentage of the dry weight shall not exceed 14%.

- Percent wear : shall not exceed 40% tested by Los Angeles Abrasion Test.
- Compressive strength : not less than 21 MN/Sq.m. (3000 Psi)

1.7.2 Stone chips must conform to ASTM C88-93, C227-90, C131-89

- It may be made of crushed stone or gravel
- Appearance shall be completely non plastic and free from any organic or other deleterious materials
- Unit weight shall not be less than 1570 kg/cu.m.
- Percent wear shall not exceed 30% tested by Los Angeles Abrasion Test.
- Nominal size same as khoa (brick aggregate)
- Grading same as brick aggregate
- Compressive strength shall not be less than 36.1MPa MN/Sq.m. (5240 Psi)

1.8 WATER

Water used in construction works shall be clear, free from oil, acid, alkali, salts, organic materials and shall be drinkable

1.9 SURKI

Surki should be made from well burnt 1st class bricks without Jhama, must pass through 64 mesh, free from clay or any other deleterious materials.

1.10 ALUMINIUM DOOR/WINDOW CHANNELS

The aluminium channels must conform to the specifications of the United States Architectural Manufacturers Association. BNBC 2.11

Channel thickness for doors	: 1.8-2.5mm.
Channel thickness for windows	: 1.2-1.8mm.
Anodization thickness	: 15 microns
Density of anodization	: 4 mg. per Sq.m.

1.11 GLASS

Glass for aluminium door and window tinted or clear should be 5mm thick and there should be no undulations

For smaller wooden panel/M.S. glazed shutters glass should be 3mm thick and there should be no undulations.

SITE OF CONSTRUCTION**2.1 SELECTION OF SITES.**

Field Engineers should play an important role in the selection of the site for proposed construction.

Selection of sites should be based upon considerations of various factors affecting the site towards its development, the cost and the stability of the proposed structures. The difficulties which may be encountered in the construction of a structure due to inaccessibility of the site should also be considered.

The site selected should be as far as possible fairly high above the normal flood level, requiring the minimum of earth filling. For an extensive scheme a topographical survey should be undertaken and a contour map prepared to find the amount of excavation or filling involved and the facilities for drainage existing in the site should be determined. Whether water and electricity would be easily available or not should also be considered.

While selecting a site in a low lying area, the field Engineer should inform the requiring body about the additional cost involvement due to earth filling and special type of foundation and floor.

2.2 STABILITY OF THE SOIL AT THE SITE

While selecting a site the soil conditions shall invariably be examined for ascertaining the nature of the ground and its bearing capacity, the probable behaviour of the soil under seasonal weather changes and/or changes in ground water level, conditions of probable unstable slopes giving rise to soil movement, or the existence of under ground pits, wells, old foundations or water courses.

The behaviour of the existing buildings, if any, in the neighbourhood may be a guide in deciding the type and the depth of the foundation of the building to be constructed. The site selected should be at a safe distance from the banks of eroding rivers, streams or canals.

2.3 ACCESSIBILITY OF THE SITE AND ITS BEARING ON COST OF THE WORK

The site selected should be easily accessible and the length of the approach road from the nearest main road to the site should be as short as possible. The area of land to be acquired should be sufficient for all the phases of a scheme. As it may be difficult to secure the ideal conditions on all points, endeavours shall be made to select a site which would have the maximum of the advantages under the given conditions.

In case if it is not possible to have an ideal site, the difficulties and disadvantages which may be encountered in the construction of the work should be recorded in writing in the proceedings of the meetings of the site selection committee, so that the extra cost may be incorporated in the estimate of the scheme.

2.4 DRAINAGE FACILITIES IN THE SITE

While selecting the site, it should be examined, whether natural facilities for the easy drainage of rain water exists in the area and whether the same can be secured effectively and economically. Care should be taken in the selection of the site to ensure that no accumulation of rain water in the drains may occur and the possibility of the back flow of the water in the drains from the outfall towards the buildings is eliminated.

2.5 PREPARATION OF THE SITE

(a) Refuse or superfluous earth, if any, on the site shall be removed as quickly as possible. Shrubs and stumps of trees, if any, shall be uprooted and removed outside the site. If it is not possible to do so, these may be stacked near the boundary of the site for the time being.

Any valuable material derived from the clearing of the site should be stored and disposed off according to the rules in the code.

(b) The trees shall be cut and their roots totally uprooted as directed by the Sub-Divisional Engineer. No tree, however, shall be cut unless it is absolutely unavoidable. The survey report must be submitted and sanctions obtained before the trees are disposed off. If white ants are found to exist in the trees, their nests should be located and dug up and the queen ant be destroyed. Holes left after uprooting of the trees should be backfilled with sand or earth, care being taken to see that on compaction the fill gains density of the original surrounding soil.

(c) Before starting the work, permanent bench marks must be established at a suitable point with reference to which the Sub-Divisional Engineer himself will layout all the important levels. The trench lines of the building should be correctly laid out and the locations for the storage and stacking of the materials definitely set on the ground. The position of the godowns, the guard shed and the access and exit roads for the trucks and carts should also be laid out and demarcated on the ground.

(d) Boundary pillars of standard designs should be fixed on the ground to define the boundary of the site.

(e) The site should be cleaned, dressed and graded properly with outward slope for the drainage of rainwater. Dressing of site shall include excavation of high area and filling the low area as required for which no separate payment shall be made to the contractor.

(f) The materials at the site shall not be spread irregularly, these shall always be kept in defined places and the site maintained neat and clean throughout the construction work.

(g) Record plans of the site showing the boundary pillars should be kept in Sub-Divisional and Divisional offices as soon as the site is taken over.

2.6 LAYING OUT OF THE BUILDING/STRUCTURES

Before commencement of excavation of trenches for foundation, the layout of the building/structure has to be finalised as per ground floor plan of the building. All the centre lines of the Architectural and Structural drawing shall have to be compared and checked for correctness.

One of the methods of laying out the building is to set out the centre line of the longest outer wall of the building in relation to boundary wall or other important points as shown in the Architectural layout plan. It may be done by stretching a string between wooden pegs with small nails fixed exactly on point on the head of the wooden peg. Wooden pegs should be 3m away from the trench of foundation. This serves as a reference line for making centre line of all the walls of the building.

The centre line of the wall which is perpendicular to the long wall is marked by setting up a right angle. Right angle is set up by forming triangles with sides 3,4 and 5 units long. If we fix the two sides of the triangle to be 3'-0" and 4'-0", the hypotenuse should be 5'-0". The dimensions should be set out with a steel tape. The alternate method of setting out of right angle is by theodolite. The instrument is also helpful in setting out of acute or obtuse angle. Some right angled projections are usually set out with mason's square.

Small brick pillars 10"x10" are constructed at a distance of 3m from the trench encasing the wooden pegs earlier fixed with nail on top. Before encasing the wooden peg its position should be finally checked. When all the centre lines are fixed, strings are stretched and fixed to nails and each centre line distances are checked again. For rectangular and square rooms, diagonals should be checked also.

Before starting the excavation, strings are stretched on the outside lines of the foundation trench and cutting lines are fixed by lime powder. If necessary, the lines may be marked on the ground by Kodali.

2.7 MAINTENANCE OF THE SITE DURING CONSTRUCTION AND FINISHING THE SITE AFTER CONSTRUCTION IS OVER

- (a) As far as possible the site should be kept clean during construction. Materials should not be stacked haphazardly here and there but kept in a planned manner in proper stacks. Care should be taken to maintain the site with proper drainage of rain and stagnant water.
- (b) The site should not be spoiled by running of trucks or carts all over it. The proposed roads should be laid out and used for carriage of materials. Base of the road may also be laid and maintained during construction.
- (c) The rejected materials i.e. under classified bricks, poor quality sand, etc., dismantled materials and such other things not to be used in the construction should be removed from the site as soon as it comes in. In case of delay of its removal under unavoidable circumstances, it should be carried to furthest corner of the site so that there is no chance of it being used by the workmen.
- (d) After the construction and improvement of site is over, it should be nicely levelled, dressed with proper grade for drainage of rain water. The site should give a finished look on aesthetic angle also.
- (e) The ground immediately adjacent to the foundation shall be sloped away from the building at a slope not less than 1 : 12 for a minimum distance of 2.5m measured perpendicular to the toe of the wall. Consideration shall be given to possible additional settlement of backfill when establishing the final ground level adjacent to foundation.

2.8 IMPROVEMENT TO SITE

In case where it is necessary to raise the site, the provision in the sanctioned estimate should be followed as to whether earth will be carried from outside or earth obtained by digging tanks from site itself. If the provision in the estimate is not fully explicit or requires some modification according to the changed circumstances, instructions of the Superintending Engineer should invariably be sought. In case of tank digging, the site plan showing the tank, building etc. should be approved by the Superintending Engineer. The tank digging should be planned in such a way that the maximum depth according to the locality is excavated before the monsoon sets in. This will not only save the cost of further excavation in order to obtain the maximum depth for getting the maximum amount of earth but also for full utility of the tank by the users of the buildings under construction. Measurement must be taken before the filling up of the tank with water.

When the earth is to be carried from outside, an estimate of the earth required on a carefully prepared pre-work contour survey should be prepared in relation to the permanent bench marks and got approved by the Superintending Engineer, along with rates of earth carriage even, though it is on a competitive tender before taking up the work. The contour survey shall form a part of tender document. The contractor shall verify the contour survey before starting the work and no subsequent claim shall be entertained. Measurement should be on the quantity of earth filled as per measurement of the contour and not on the stack of carried earth. There shall not be any question of payment to contractors on measurements on trucks or carts. Anybody doing this shall be held personally responsible for this. Final payment shall be made after 12(twelve) months from the date of completion of work. The contractor shall supply additional earth at his own cost, if required, to bring the site to proposed level.

2.9 SITE OFFICE, WORKSHED, GODOWN, GUARD SHED IN THE SITE

Setting of the above should be judiciously done so that it will not be necessary to dismantle or remove it before finally completing the work and handing over the site. In order to minimise the cost on the above, prefabricated houses of steel, concrete or timber should gradually be introduced. The work shed, a site office should give a presentable look with preferably steel furniture. All these, however, will depend on the magnitude of the proposed construction and the money spent on it should bear a reasonable proportion on the cost of the proposed work.

2.10 ARBORICULTURAL OPERATION IN THE SITE

Due importance should be given to arboricultural operation at the site as soon as the work is started. Suitable trees should be planted and maintained, so that at the time of handing over the site, the trees are grown sufficiently. Care should be taken not to plant trees too near to the building. Arboriculture Division shall be informed well in advance for the preparation of estimate and approval by competent authority.

SOIL INVESTIGATION

3.1 INTRODUCTION

Knowledge of the underground soil condition at a site is prerequisite to the economical design of the sub-structure elements. Attempt to save little money bypassing soil investigation only to find after the design is completed and construction has started that the foundation conditions encountered necessitate a new design is a false economy. For major structures site investigation is necessary but for smaller structures there is a wide practice of little or no exploration.

3.2 TYPES OF ACTIVITIES

Subsoil exploration process may be grouped into three types of activities, such as :

- 1) Reconnaissance : This method includes geophysical measurements sounding or probing.
- 2) Exploration : Exploratory methods involve various drilling techniques.
- 3) Detailed Investigation : The detailed investigation usually requires undisturbed samples or field tests.

While planning the exploration programme, the Engineer should keep in mind the purpose of the programme and the relating cost involvement. It may be more economical to provide a conservative foundation design, if the history of the soil life reveals that the soil condition is good than to go for elaborate boring and testing programme. Often an indication of the extent of an exploration programme can be estimated from the history of foundation success and failures in an area. In this phase of the programme experience of the area is very helpful. Reconnaissance of the area in the form of field trip can reveal information on the type and behaviour of the adjacent structures, such as cracks, noticeable sags etc.

3.3 TRIAL PITS

After reconnaissance of the area, a preliminary site investigation in the form of test pits to establish the types of materials, stratification of the soil and possibly the location of ground water level may be undertaken. For small project, this step may be sufficient to establish foundation criterion in which case the exploration programme is finished. Ground investigation is normally done by bore holes but where only shallow depths are to be investigated and where ground water problems are not envisaged, trial pits may prove more versatile and economical. Boreholes may be necessary on water logged sites where it is impracticable to excavate trial pits without dewatering.

These trial pits should be sufficient in number to represent conditions over the entire area of the proposed building. The depth of pit should not be less than 5'-0".

Before going for a detail soil investigation, Site Engineer should explore soil by test pit and if he is satisfied that the test pit investigation is not enough then only, he shall propose for detail soil

investigation. The Site Engineer should keep in mind that in most of the cases, a test pit is enough to determine the parameters for foundation design.

For important projects or where the soil is of poor quality and/or erratic in nature, a more detailed investigation may be undertaken in which case samples are collected for shear-strength determination and settlement analysis.

3.4 DATA REQUIREMENTS

The soil-site investigation should provide data but not limited to the following items :

1. Location of ground water level
2. Bearing capacity of the soil
3. Selection of alternative types and/or depth of foundation
4. Data on soil parameters and properties
5. Settlement predictions
6. Potential problems concerning adjacent property
7. End bearing value and skin friction for pile design

3.5 NUMBER AND POSITION OF TRIAL PITS AND BORE HOLES

The location and spacing of pits and boreholes shall be such that the soil profiles obtained will permit a reasonably accurate estimate of the extent and character of the intervening soil masses and will disclose important irregularities in sub-surface conditions. For building structures the following guidelines may be followed:

- (a) For large areas covering residential colonies or big projects, the geological nature of the terrain will help in deciding the number of boreholes or trial pits. The whole area may be divided into grids and at the discretion of the Site Engineer, the number of trial pit or borehole points is selected. At least $\frac{2}{3}$ rd of the required number of borings or trial pits shall be located within the area under the building.
- (b) In compact building sites, one borehole trial pit in each corner and one at the centre shall be adequate.
- (c) For small and less important buildings, one borehole or trial pit at the centre will suffice.

3.6 DEPTH OF EXPLORATION

The depth of exploration shall depend to some extent on the site and type of the proposed structure, on certain design considerations such as safety against foundation failure, excessive settlement, seepage and earth pressure. The following guidelines shall be followed in determining the depth of exploration.

- (a) Normally, the depth of exploration shall be two times the estimated width or least dimension of the footing below the foundation level. If pressure bulbs for a number of loaded areas overlap, the whole of the area may be considered as loaded and exploration shall be carried down to one and half times the least dimension of the building. In weak soils, the exploration shall be continued to a depth at which the loads can be carried by the stratum in question without undesirable settlement or shear failure.
- (b) In case of pile foundation, the depth of exploration shall be equal to the width of the structure, subject to a maximum of 10m beyond the tip of the pile.
- (c) The depth to which weathering process affects the soil deposit shall be regarded as the minimum depth of exploration for a site and this shall be taken as 2m.

3.7 METHOD OF EXPLORATION AND RECORD

Listed below are some common methods of sub-soil exploration other than trial pit:

- a) Auger boring
- b) Shell and auger boring

- c) Wash boring
- e) Geophysical method
- g) Rotary boring
- d) Sounding/probing
- f) Percussion boring

The choice of method shall depend on the topography, type of ground to be investigated, ground water conditions, the type of building envisaged and technical requirements, amount of existing information, expected variability of soil, external constraints such as availability of plants, access, cost and time available. But technical requirements of the investigation rather than cost should be the over-riding factor in the selection of investigatory method.

The record of all boring shall include but not limited to the following information:

- a) Size of the casing (if used)
- b) Number of blows per 300mm required to drive the sampling spoon
- c) The elevation of the ground surface referred to an established datum
- d) Location and depth of boring and its relation to the proposed construction
- e) Elevation at which samples are taken
- f) Elevation of the boundaries of soil strata
- g) Description of soil strata encountered and any particular unusual or special condition such as loss of water in the earth and rock strata, boulders, cavities and obstructions, use of special type of samplers, traps etc.
- h) The level of ground water together with a description of how and when ground water level was observed

3.8 LABORATORY TEST

The following soil test shall be performed in the laboratory for proper evaluation of soil parameters:

1. Grain size analysis
2. Specific gravity
3. Unit weight (wet & dry)
4. Natural moisture content
5. Unconfined compression strength
6. Direct shear
7. Consolidation test

3.9 APPROXIMATE BEARING CAPACITY BASED ON SPT

The blow counts (blows per 300 mm or 12 inch of penetration) in clays, silts and sands for SPT has been correlated with the angle of shearing resistance of granular soils by Peck, Hanson and Thorburn. Tarzazghi and Peck has given the following approximate correlation with the consistency of cohesive soil

N Value (Blows/ 300mm or 12 in)	Consistency	Approx. unconfined compressive strength	
		KN/M ²	U.S. Ton/ft ²
Below 2	Very soft	Below 25	Below 0.25
2-4	Soft	25-50	0.25-0.50
4-8	Medium	50-100	0.5 - 1.0
8-15	Stiff	100-200	1.0 - 2.0
15-30	Very stiff	200-400	2.0 - 4.0
Over 30	Hard	Over-400	Over 4.0

The indicative values of unconfined compressive strength correlated to penetration number should be used cautiously. These values may be used only as a guideline.

3.10 FIELD LOAD TEST

A semidirect method to estimate the bearing capacity of soil in the field is to apply a load to a model footing and measure the amount of load necessary to induce a given amount of settlement.

Excavate a pit to the depth at which the test is to be performed. The test surface shall be levelled at the elevation of the proposed test for a clear distance of at least 1.5m around the test plate. The loaded area shall be square and at least 600mmx600mm. In the even ground water is present immediately below, at or above the level required to be tested, dewatering facilities shall be installed to maintain ground water at minimum of 1.2m below the level of the test plate during the preparation and during the test period.

A load is placed on the plate and settlements are recorded from a dial gauge accurate to 0.25mm. Observations on load increments should be taken until the rate of settlement is beyond the capacity of the dial gauge. Load increments should be approximately one fifth of the estimated bearing capacity of the soil. Time intervals of the loading should not be less than 1 hour and should be approximately of the same duration for all the load increments.

The test should continue until a total settlement of 25mm is obtained, or until the capacity of the testing apparatus is reached. After the load is released, the elastic rebound of the soil should be recorded for a period of time at least equal to the duration of a load increment.

Load settlement and settlement log time curve may be drawn and from there ultimate soil pressure may be calculated.

For extrapolating the load test results to full size footing, it can be said that the bearing capacity of clay is essentially independent of the footing size or

$q_{\text{footing}} = q_{\text{load test}}$

In sands and gravels the bearing capacity increases linearly with the size of footing.

Soil load bearing test shall not be applicable when the proposed bearing stratum is underlain by a stratum of lower strength unless analysis indicate that the presence of such lower stratum shall not create excessive settlement of the building.

One of the principal limitations of a loading test or plate bearing test for foundation investigation is that the loaded area is usually small in relation to proposed foundation and that the settlement is controlled by the material within a zone extending in depth to about $1\frac{1}{2}$ times the minimum dimension of the loaded area. Thus the presence of soft strata which may contribute to serious foundation settlement will not be evaluated by loading tests if the soft strata in question are beyond the influence of the loaded area.

3.11 CONCLUSION

When the field investigations and laboratory tests are over, a detailed report containing but not limited to data as detailed in section 3.4 and 3.8 along with charts, graphs and other information shall be prepared for the preparation of structural design and also for site use during construction.

Field Engineer shall inform the design office about any variation, if encountered, at the time of execution of the project.

FOUNDATION**4.1 INTRODUCTION**

The sub-structure or foundation is that part of the structure which is usually placed below the surface of the ground and which transmits load to the underlying soil. Foundation supports superstructure but it may contain various parts or units of its own. The term foundation generally includes the entire supporting structure. The term must not be confused with the word footing, which generally applies only to that portion of the structure which delivers the load to the soil.

The foundation serves to transmit to the soil beneath it, its own weight, the weight of the superstructure above it and any force which may act upon them. A foundation is, therefore, the connecting link between the superstructure and the soil.

A properly designed foundation is to support the loads resting on it and to distribute them in a satisfactory manner over the contact surface of the soil layer on which it rests. In order to be satisfactory, this distribution must not produce excessive stresses within the soil mass at any depth beneath the foundation.

The importance of foundation is self evident since no structure can endure without an adequate foundation.

4.2 GENERAL REQUIREMENTS

Due to the load of the structure, the soil below is compressed noticeably and cause the supported soil to settle. The two essential requirements in the design of foundation are :

1. That the total settlement of the structure should be limited to a tolerably small amount.
2. That differential settlement of various parts of the structure shall be eliminated as nearly as possible.

With respect to possible structural damage, the elimination of differential settlement i.e. different amounts of settlement within the same structure, is even more important than limitations on uniform overall settlement.

To limit the settlements, as indicated, it is necessary :

- a) to transmit the load of the structure to a soil stratum of sufficient strength.
- b) to spread the load of the structure over a sufficiently large area of that stratum to minimize bearing pressure.

If soil with adequate physico-mechanical properties is not found immediately below the structure, it becomes necessary to use deep foundation such as piles or caissons to transmit the load to deeper, firmer layers. If satisfactory soil directly underlies the structure, it is merely necessary to spread the load by footing or other means.

A foundation should be designed in such a way that there is no possibility of tilting of the structure. If the foundation area for the structure is such that the centre of gravity of the loads does not coincide (in plan) with the centre of gravity of the foundation area, the consequent bearing reaction will be non-uniform. At the edge closer to the centre of gravity of the load the pressure intensity will be higher resulting in a greater settlement of the soil at this edge. This will result in tilting of the structure in this direction. Hence it is better to design the foundation area such that the centre of gravity of the loads will coincide with the centre of gravity of the foundation area so that the soil reaction will be of uniform intensity.

A foundation must be able to satisfy several stability and deformation requirements such as:

- a) Depth must be adequate to avoid lateral expulsion of materials from beneath the foundation, particularly footings and mats.
- b) Depth must be below the limits of seasonal volume changes such as freezing and thawing or the zone of active organic materials.
- c) System must be safe against overturning, rotation, sliding or soil rupture (shear strength failure).
- d) System must be safe against corrosion or deterioration due to harmful materials present in the soil.
- e) The foundation should be economical in terms of both materials as well as method of installation.
- f) Total earth movements (generally settlements) and differential movements should be tolerable to the foundation elements and/or any superstructure elements.

4.3 TYPES OF FOUNDATION

Broadly, foundations may be classified into two categories depending upon the depth of the load transferring member below the superstructure.

- A. Shallow foundation
- B. Deep foundation

Terzaghi defined a shallow foundation as one in which the depth to the bottom of the footing is less than or equal to the least dimension of the footing.

Shallow foundations may be classified under the following classes :

4.3.1 Spread footing

- a) Isolated column footings under individual columns. These may be square, rectangular or occasionally circular in plan. It represents the simplest and most economical type.
- b) Wall footing either flat or stepped, which supports bearing wall.
- c) Combined footing supporting two column loads.
- d) Strip footing provided for more than two columns in a row.
- e) Strap footing consists of two column footings connected by a strap beam.

When property rights prevent the use of footing projecting beyond the exterior walls, a strap footing is used which enable one to design a footing which will not project beyond the outer column.

4.3.2 Mat foundation

Individual or combined column footings are the most frequently used types of spread foundations on soils of reasonable bearing capacity. If the soil is weak and/or column loads are great, the required footing areas become so large as to be uneconomical. In this case, unless a deep foundation is called for by soil conditions a mat or raft foundation is resorted to. This consists of a solid reinforced concrete slab which extends under the entire building and which, consequently,

distributes the load of the structure over the maximum available area. Such a foundation, in view of its own rigidity, also minimise differential settlement. It consists in its simplest form, a concrete slab reinforced in both directions. A form which provides more rigidity and at the same time, is often more economical consists of an inverted beam and girder floor. Girders are located in the column lines in one direction, with beams in the other, mostly at closer intervals. If the columns are arranged in a square pattern, girders are equally spaced in both the direction and the slab is provided with two way reinforcement.

Inverted flat slabs with capitals at the bottom of the columns are also used in mat foundation.

Deep foundations are existant in following 2 types :

- a) Pier foundation
- b) File foundation

4.3.3 Pier foundation

A shaft foundation having a ratio of depth to base width greater than 4 shall be considered as pier foundation. The base of a pier may rest directly on a firm stratum or on piles. Caisson foundation shall also fall under the category of pier foundation. A caisson is a hollow shaft or box that is sunk into position and becomes the outer part of finished pier.

4.3.4. Pile foundation

A pile is a slender member which transfers the load either through its lower end into a strong stratum or may transfer its loads to the surrounding soil by friction or both. Piles may be required to carry uplift loads when used to support tall structures subjected to overturning moments from wind or other loads. Piles used in marine structures are subjected to lateral loads from impact of berthing ships and from waves. Combination of vertical and horizontal loads are carried where piles are used to support retaining walls, bridge piers, abutment and machinery foundation.

- a) Driven Cast-in-situ concrete piles

Forming a pile by driving a steel casing or concrete shell in one or more pieces which may remain in place after driving or withdrawn and inside filled with concrete, fall in this category of piles. Sometime an enlarged base is formed by driving out a concrete plug.

- b) Bored cast-in-situ concrete piles

These are piles formed by concreting bore holes formed by jetting, auguring, rotary drilling, percussion drilling with or without using bentonite mud circulation. Pre-excavation shall be carried out in a manner that will not impair the carrying capacity of the piles already in place or damage adjacent structure. These piles shall be tested for integrity by load test or by any other test method.

- c) Driven precast concrete piles

Pile structures capable of being driven into the ground and able to resist handling stresses shall fall into this category of piles. Piles in this category are cast in a central casting yard to the specified length, cured and then transported to the construction site. If space is available and sufficient quantities of piles needed, a casting yard may be provided at the site to reduce transportation cost.

Precast piles can be designed and manufactured in ordinary reinforced concrete or in the form of pretensioned or post-tensioned prestressed concrete members. The ordinary reinforced concrete pile is preferred for a project where small number of piles is required and where the cost of establishing a production line for prestressing work on site is not justifiable and where the site is too far from an established factory to allow the economical transportation of prestressed unit from factory to site.

Precast concrete piles in ordinary reinforced concrete are usually square or hexagonal and of solid cross section of units of short or moderate length. Often square piles with corners chamfered are used. It is usual to provide the pile with a cast iron shoe to prevent the end of the pile from breaking, particularly when it strikes a boulder underground. The pile shoe should be coaxial with the pile and firmly fixed to concrete.

Precast piles using ordinary reinforced concrete are designed for bending stresses to be caused during pickup and transportation of them to site, bending moment from lateral loads and for providing sufficient resistance to vertical loads and any tension forces which may be developed during driving.

d) Under-reamed concrete piles

These are bored cast-in-situ piles having one or more bulbs formed by enlarging the bore hole for pile shaft.

e) Timber piles

Timber piles are made of tree trunks with the branches trimmed off and driven with the small end down. Occasionally the large end is driven for special purposes or in very soft soil where the butt end can rest on a firmer stratum. For hard driving, the tip may be provided with a metal shoe, otherwise it is pointed somewhat or cut off square.

There are limitations on the size of the tip and butt end as well as the magnitude of misalignment. For alignment the requirement is that a straight line from the centre of the butt to the centre of the tip should lie within the pile shaft.

If the timber pile is below the permanent water table, it appears that it will last indefinitely. When a timber pile is subjected to alternate wetting and drying, the useful life will be relatively short, perhaps as little as 1 year, unless treated with a wood preservative. Although creosote or other preservatives extend the life of timber in damp or dry conditions, they will not prolong its useful life indefinitely. Therefore, it is the usual practice to cut off timber piles just below the lowest predicted ground water level.

Bark should be removed from round timbers where these are treated with preservatives. If this is not done, the bark reduces the depth of impregnation. Also the bark should be removed from piles carrying uplift loads by skin friction in case it should become detached from the trunk, thus causing the latter to slip. Only structural timber shall be used for piles used for transmitting imposed load to soil. When used as compaction piles, above requirements may be relaxed.

Damage to the timber pile can be minimized by reducing as far as possible the number of hammer blows necessary to achieve the desired penetration and also by limiting the height of drop of the hammer.

Driving of timber piles usually result in the crushing of the fibres on the driving end, which can be controlled somewhat by using a driving cap or a metal band around the butt. Driving may also result in a broken pile in hard soil or soil containing boulders. A sudden increase in pile penetration may be an indication of a broken pile shaft.

After driving, the broomed end is cut square and if previously treated, any observed cuts, holes should be coated with preservatives.

The use of timber piles in Government buildings has long been discouraged and is not considered at present.

D) Other piles

Piles such as pipe piles, steel H-piles, bamboo piles, composite piles etc. are not in use in Government buildings.

4.4 GENERAL DESIGN CONSIDERATION OF FOUNDATION

4.4.1 Wall footing

a) Masonry stepped wall footing

Masonry stepped wall footing under a continuous wall of a building is designed on the simple principle of distribution of the wall load per linear length along with other loads carried by the wall and self weight of foundation on an width sufficient to distribute the load within the

allowable bearing capacity of the soil. A slab of plain concrete over a brick flat soling is laid at the bottom of foundation to transmit the load to the ground. Projections are left equally on both sides of the concrete slab and stepped footings in brick works are gradually built up over it until the designed thickness of the wall below the ground level and above it is obtained. Isolated brick column foundations are also done like this.

The projection of the plain concrete slab beyond the lowest brick step shall not be more than the thickness of the slab. Generally, the proportion of the bottom plain concrete is 1:3:6 by volume.

b) Reinforced concrete wall footing

Plain concrete slab at the bottom of the footing as stated above can not be extended as desired unless the slab thickness is increased sufficiently, because the plain concrete slab is incapable of taking tension. As such if we increase the projection without increasing the thickness, the slab shall crack. As an alternative to this, a reinforced concrete footing may be adopted.

This type of foundation has the advantage that the volume of brick work in the stepped footing is reduced. Considerable economy can thus be attained in the volume and the cost of brick work in foundation. On the other hand, due to the provision of reinforcement at the bottom slab, the cost will increase. Therefore, the choice between the plain and reinforced concrete footing slab shall depend on the relative cost between the two and other allied factors like workability, availability of materials etc. The threshold of cost benefit between the two types should be established first before selecting the type

The simple principle of beam action with only minor modification shall apply to wall footing design. Though for a reinforced concrete wall, the maximum bending moment shall occur at the middle of the width of the footing, the very large rigidity of the R.C.C. wall modifies this situation and it is satisfactory to compute the moment at the face of the wall and necessary reinforcement and thickness are provided to resist that movement. Transverse reinforcements are provided for shrinkage stresses. The thickness of slab shall not be less than 9" with a clear cover of 3" at the bottom.

For a footing on masonry walls, the maximum moment is computed midway between the middle and the face of the wall since masonry is generally less rigid than concrete.

The calculation of bond stress is based on the shear for the same section and design provision for bond is the same as for beam.

For determining shear stresses, the vertical shear force is computed, as in beams, at a distance 'd' from the face of the wall for R.C.C. walls and midway between face and middle of the wall for masonry walls where 'd' is the effective depth of the slab.

It is generally not economical to use web reinforcement for R.C.C. wall footings.

On slopped sites, foundations should be horizontal but stepped at each change of levels. They should be lapped at the steps for a distance at least equal to the thickness of the foundation base or twice the height of the step, whichever is greater. The steps should not be greater than the thickness of the foundation base.

4.4.2 Isolated column footing

R.C.C. columns in buildings with load bearing walls, may be provided to carry verandah loads or the loads of the R.C.C. floors and roofs, the columns being situated free of walls. In R.C.C. frame structure, the columns may carry the loads of the panel walls as well as those of floors and roofs. In all these cases R.C.C. column footings are provided to spread the load on the soil within the allowable bearing capacity.

Single column footings are usually square. Rectangular footings are used if space restrictions dictate the choice or if the supported columns are of elongated rectangular cross section.

In the simplest form, they consist of a single slab. Another type is that where a pedestal or cap is interposed between the column and the footing slab, the pedestal provides for a more favourable

transfer of load and in many cases is required in order to provide the necessary length of dowels. All parts of the footing must be poured in a single pour, in order to provide monolithic action.

Sometimes slopped footings are used. They require less concrete than flat surface but the concreting should be done with proper care to compact the concrete on slope.

Single column footings represent cantilevers projecting out from the column in both direction and loaded upward by soil pressure. Corresponding tension stresses are caused in both directions at the bottom surface. Such footings are, therefore, reinforced by two layers of steel, perpendicular to each other and parallel to the edges.

The required bearing area is obtained by dividing the total load, including the weight of the footing, by the selected bearing pressure. Weights of footing at this stage, must be estimated and weighs approximately 6-10% of the column load, the former value applying to the stronger types of soils.

In computing bending moments and shears, only that part of the upward pressure which is caused by the column load is considered. The weight of the footing does not cause shear or moment.

The footing is designed for shear, bending moment and bond stresses. In footings which support R.C.C. column, the critical sections for bending moments are located at the faces of the column.

In square footings, the reinforcement is uniformly distributed over the width of the footing in each of the two layers i.e. the spacing of the bars is constant. The moments for which the two layers are designed are the same. However, the effective depth for the upper layer is less by 1 diameter than that of the lower layer. Consequently, the required steel area is larger for the upper layer. Instead of using different spacings or different bar diameters in each of the two layers, it is customary to determine steel area for the upper layer and to use the same arrangements of reinforcement for the lower layer.

In rectangular footings, the reinforcement in the long direction is uniformly distributed over the pertinent (shorter) width. In locating the bars in the shorter direction, the code provides a modification which should be followed.

The critical section for bond are the same as those for bending. Bond may also have to be checked at all vertical planes in which changes of section or reinforcement occurs.

The average shear stress in the concrete can be taken to act on vertical planes laid through the footing at a perimeter distance $d/2$ from the faces of the column, where d is the effective depth of the footing.

The method for locating the critical sections both for bending, bond and shear are not directly applicable to footings supporting round columns, since, in this case, the face of the column needs special definition. The code specifies that, for this purpose, the face of the column, shall be taken as the side of the square having the same area as the circular column. The same holds for octagonal columns and round and octagonal pedestal.

Code rule should be followed for clear cover of reinforcements in foundation.

4.4.3 Combined footing

1) Rectangular type

A combined R.C.C. footing is provided when two columns are so close that the footing if designed to carry the loads of the columns separately, will be very close or be overlapped. They are also necessary when the face of an exterior column coincides with or is close to the property line so that a single footing under the column would project beyond that line. Eccentric single footing would result in unequal bearing pressure distribution with the possibility of bending of the footing and consequent bending of the column. In such cases, a combined footing, supporting the exterior and the adjacent interior column, can be so proportioned that the centroid of the footing area coincides

with the resultant of the column loads, producing an even pressure distribution and uniform settlement without tilting.

A combined footing may be rectangular in plan or trapezoidal. The form is so chosen as to make the centroid and the resultant coincide. Hence, rectangular footings are suitable for interior columns, or for exterior columns, when the exterior column has lighter load and the footing may be extended beyond the interior column as far as possible. The trapezoidal shape is required if column loads are unequal and if for any reason, the footing can not be extended appreciable distance beyond the heavier column.

The procedure of the design of a combined footing without a connecting grade beam may be summarized as follows :

- a) Ascertain the loads on both columns and their distance apart. Find the resultant of the column load.
- b) Estimate the weight of the footing. As a crude rule, 6 to 10 percent of the combined column loads can be taken as the approximate weight of the footing. Add the weight of the footing to the column load to get the area of the footing by dividing it with allowable bearing pressure.
- c) Select the width of the foundation and find the length of footing.
- d) Using the resultant of the loads in steps (a) select the plan dimension of the footing to obtain a uniform soil pressure that does not exceed the safe bearing capacity of the soil. In order to satisfy this the C.G. of the column loads should coincide with the C.G. of the foundation plan.
- e) Calculate the maximum bending moment any where in the length of the footing and also punching shear.
- f) Draw shear and bending moment diagram.
- g) Calculate the effective depth 'd' both for bending moment and punching shear stress consideration. Adopt the greater value as the final effective depth. Punching shear should be checked on a perimeter section at a distance $d/2$ around the column.

Longitudinally, the footing represents an upward loaded beam spanning between column and cantilever beyond interior column. Since this beam is considerably wider than the columns, the column loads are distributed crosswise by transverse beams, one under each column.

- h) Calculate the shear force at all critical sections and check for safe shear stress. Critical section for shear is at a distance 'd' from the face of the column.
- i) Calculate the area of main steel required to resist bending moments at various sections.
- j) Check for safe bond stress.
- k) Calculate the transverse steel required under each column. The effective width of the transverse beam shall be equal to that of the column plus, on either side of the column, a strip of width equal to one half that of column or one half the depth of the footing, whichever is smaller.

If the columns are connected longitudinally by a grade beam, the slab underneath shall be designed as cantilever slab from the beam with load equal to net bearing pressure of the soil and the beam shall be designed for bending, shear, diagonal tension, punching shear, bond etc.

2) Trapezoidal type

This type of footing may be used to carry two column loads when space outside the structure is too limited for a spread footing and the exterior column carrying the largest load. The location of the resultant force will then be close to the larger column and doubling the centroid distance will not provide a length sufficient to reach the other column, without introducing an eccentricity into the soil pressure diagram. A trapezoidal footing is required in this case unless the distance between the

column is so great that a cantilever or strap footing would be more economical. A trapezoidal solution exists between the limits:

$$\frac{L}{3} < x' < \frac{L}{2} \text{ where}$$

L = out to out column faces distance

x' = centroid distance from outer face of the larger column.

For the most economical solution, simultaneous equations based on minimum required area of the trapezoid and for the location of the centroid of area can be used to find width dimensions. With the width dimensions established the footing may be treated similar to combined footing in drawing shear and moment diagram. For simplicity, the column loading will be considered as point loads.

4.4.4 Strap footings

In a strap or connected footing, the exterior footing is placed eccentrically under its column, in order that it does not project beyond the property line. Such a position would result in an uneven distribution of the bearing pressure and tipping of the footing. To counteract this tendency, the footing is connected by a beam or strap to the nearest column.

A strap footing may be used where distance between column is so great that a combined or trapezoidal footing becomes quite narrow, with resulting high bending moment.

The footing areas are so proportioned that the pressure under each of them is uniform and is same under both the footings. To achieve this, it is necessary, as in other combined footings, that the centroid of the combined area of the footings coincide with the resultant of the column loads.

Since the strap is designed for moment, either it should be formed out of contact with soil or the soil should be loosened for several inches beneath the strap so that the strap has no soil pressure action on it. For simplicity of analysis, if the strap is not very long, the weight of the strap may be neglected.

The strap should be strong enough to transmit the eccentric moment from exterior column without rotation. Maximum rigidity of strap is obtained by running the strap from column to column rather than footing to footing.

4.4.5 Strip footing

Strip footing is an extension of combined footing, where more than two columns are connected by a single footing. These footings are generally designed by assuming a linear stress distribution on the bottom of the footing and the resultant of the soil pressure coincided with the resultant of the loads (centre of gravity of the footing), the soil pressure is assumed to be uniformly distributed. The linear pressure distribution implies a rigid footing on homogeneous soil. The actual footing is generally not rigid nor is the pressure uniform beneath it, but it has been found that solutions using this concept are adequate. The concept also results in rather conservative design. The footing loaded by more than two columns is statically determinate, the reactions (column loads) are known as well as the distributed loading i.e. the soil pressure.

Design of a strip footing consists in determining the location of the centre of gravity (C.G.) of the column loads and using length and width dimensions such that the centroid of the footing and the centre of gravity of the column loads coincide. With dimensions of the footing established, width of the connecting grade beam selected, shear and moment diagrams can be drawn. The slab may be designed as a cantilever slab from the face of the beam. The depth of the beam may be calculated from shear and moment. Reinforcing steel may be provided for bending. Critical shear, diagonal tensions may be calculated at critical sections. The maximum positive and negative moments are used to design the reinforcing steel and will result in steel in both bottom and top of the beam.

In selecting dimensions for the strip footing with vertical columns the length dimension is somewhat critical if it is desired to have shear and moment diagrams mathematically close as an error check. This means that, unless the length is exactly same to the computed value from the

location of the C.G. of the columns, an eccentricity will be introduced into the footing, resulting in a non-linear earth pressure diagram. The actual as built length, however, should be rounded to a practical length, say, to the nearest 0.25 or 0.5 ft. (7.5 to 15 cm).

The column loads may be taken as concentrated loads for computing shear and moment diagram. For design the shear and moment values of the edge of the column should be used. The resulting error is negligible.

To avoid large bending moments, it is advised to restrict the number of columns in one strip footing to 4-5 columns.

4.4.6 Mat foundation

A mat foundation is a large concrete slab which transmits loads from several columns in a building or the entire building loads to the ground. The most common mat design consists in a flat concrete slab several feet thick and with continuous two way reinforcement both at top and bottom.

Substantial rigidity against deflection can be obtained if a basement is provided between R.C. raft and R.C. ground floor slab, the two being connected with R.C. walls and columns with rigid joints.

4.4.7 Pile foundation

If soil conditions require the use of piles, these are usually driven in clusters, one to each column and the load is transferred from the column to the pile through a footing (Pile cap).

The size of the footing is determined by the required number of piles and by the spacing between them, which usually, for friction piles, is not less than 3'-0" for concrete piles or 2.5 ft. for timber or H-piles. End bearing piles are sometimes driven at closer distances.

The tops of the piles must be securely embedded in the footing. For this purpose the bottom of the footing is located not less than 6 inches below the top of the piles and the distance from the centre of outside pile to the edge of footing is not made less than 1.5 ft. Reinforcement is located at a distance of 3 inch above the top of the pile.

Occasionally, individual piles can not be driven to the design depth, with the result that their top remain above the planned elevation. Under no circumstances, should the footing reinforcement in such cases be bent round the protruding pile. Such piles must be cut to the required elevation before the footing is cast.

In designing the footing, the load from the column is assumed to be uniformly distributed to all piles in the cluster. For this purpose, piles must be arranged symmetrically about the axis of the column. The net load per pile i.e. the column load divided by the number of piles, is then assumed to act as an upward load on the footing concentrated at the centre of the pile. The critical section for moment and bond are the same as for footings resting on soil.

While for bending computations the pile reactions are assumed to be concentrated at the pile centres, in computing shear forces, account is taken to the fact that these reactions are actually distributed over the bearing area of the pile. The fact that shear is usually the critical feature which determine the depth of a footing is the reason for the greater refinement in this determination.

In computing the external shear, the entire reaction from any pile whose centre is located 6" or more outside the section, shall be assumed as producing shear on the sections, the reaction from any pile whose centre is located 6 inch or less inside the section shall be assumed as producing no shear on the section. For intermediate position of the pile centre, the portion of the pile reaction to be assumed as producing shear on the section shall be based on straight line interpolation between full value at 6" outside the section and zero value at 6" inside the section.

4.5 NEGATIVE SKIN FRICTION

When a fill is placed on a compressible soil deposit, consolidation of the compressible layer will occur. When a pile is driven into the compressive materials (either before or after fill materials)

before consolidation is complete, the soil will move downward relating to pile. This relative movement will develop negative skin friction between the pile and the moving soil. According to investigation, this negative skin friction can some time exceed the allowable load for pile section.

The principal effect of negative skin friction is the increase of the axial load in the pile. Negative skin friction can produce larger tension stresses when the effect is from expansive soils, specially if no or insufficient gap is left between soil and pile cap and the soil expands against cap.

The effect of negative skin friction can be minimized by employing slender piles but more positive measure is desirable to reduce the magnitude of the drag down forces. In the case of bored piles this can be done by placing in situ concrete only in the lower part of the pile within the bearing stratum and using a precast concrete element surrounded by a bantonite slurry within the fill. Negative skin frictional force on precast concrete piles can be reduced by coating the portion of the shaft within the fill with soft bitumen.

The bitumen is heated to 180°C (Maximum) and sprayed or poured into the pile to obtain a coating thickness of 10mm (3/8"). Before coating, the pile should be cleaned. The bitumen slip layer should not be applied over the length of the shaft which receives support from skin friction and a length at the lower end of ten times the diameter or width of the pile should remain coated if the full end bearing resistance is to be mobilized.

Negative skin friction is a most important consideration while piles are installed in groups.

4.6 CONSTRUCTION METHOD FOR DEEP FOUNDATION.

4.6.1 Pier foundation

Pier is underground structural member which is constructed on the ground in lifts and sunk inside the ground by excavating the soil inside. After the first lift is built and sunk, the second is built over it and the whole is sunk again. The process is repeated until the well is sunk to the desired depth.

The bottom of the well is located at level where the soil can support the load coming upon it, both by direct bearing and by the frictional resistance of the wall surface. When the sub-soil consists of loose filled up materials or when there is a danger of scour, which may wash the foundation if it was located near the ground level, this type of foundation is used. A R.C.C. well kerb of a triangular section with a steel plate fixed to it at the lower rim to serve as a cutting edge, is built at the position of the proposed well and cured properly. The well made with brick work in cement mortar with bars are adequately anchored to the well kerb. After the brick steining is properly cured, the earth inside the well and below the kerbs, are excavated and removed. The well sinks due to its own weight. If it does not, loading materials, called the kentledge are added on top.

The process is repeated until the well is sunk to the desired depth. The inside of the R.C.C. well kerb is next plugged with cement concrete. The inside of the well is then filled with sand which is compacted in layers and one R.C.C. cap is built on top of the well. R.C.C. footings and columns are built over the R.C.C. cap.

Advantages of using caisson or drilled pier foundation :

1. Economy where piers can be used.
2. Elimination of pile caps, as a single pier can often be used beneath a column.
3. Absence of noise and vibration usually associated with pile foundation.
4. Elimination of heave or ground displacement associated with driven piles. This is specially important if adjacent buildings are close to the foundation location.
5. Relative ease of inspection of the sites and bearing surfaces by sending an inspector down the pier shaft.

Some disadvantages of using caisson foundation :

1. Operations affected by encountering suspended boulder. Some large rocks may be broken and removed through shaft:
2. Requires a thorough soil investigation, since it is not usually practical to perform load test on a pier.
3. Operations are affected by weather. Drilling and/or concreting during rain is undesirable and impossible.

4.6.2 Pile foundation

4.6.2.1 General requirements

Pile foundations shall be installed under the direct supervision of a qualified Engineer with professional knowledge in the field of soil mechanics and pile foundation, who shall certify that the piles as installed satisfy the design criteria. Pile shall be installed on the basis of a site investigation report that will include boring, test pit or other surface exploration at locations and depths sufficient to determine the position and adequacy of the bearing soil unless adequate data is available upon which the design and installation of the piles can be based. The report shall include but not limited to :

- a) Recommended pile type and their capacities
- b) Designation of bearing stratum or strata
- c) Driving and installation procedure
- d) Field inspection procedure
- e) Pile load test, integrity test requirements
- f) Durability and quality control measures requirements of pile materials

Tender document should contain a pile layout and detail specification of such items as materials to be used, fabrication methods, penetration depth, site investigation report and site plan showing existing surface levels, proposed regrading levels and operating levels for the piling rigs. The site investigation should be undertaken by the site Engineer before inviting tenders for the piling.

The Sub-Divisional Engineer/Assistant Engineer shall maintain a drawing sheet with the foundation plan and the layout of the each pile drawn on it. Each pile shall be described by a number.

The responsibility for setting out the piles lies with the contractor, but the site Engineer should check the position of the piles time to time, since if these are inaccurately placed, the remedial measures can cost very high.

4.6.2.2 Cast-in-situ piles

A. Construction materials

- a) Aggregates : 20 mm down graded, washed and cleaned, crushed/rounded stone conforming to the specification BS882 or AASHTO M6 V M80 shall be used as coarse aggregate.

Final aggregate shall be clean and washed sand (F.M minimum 2.0) free from mica and conforming to BS882.

- b) Cement shall be Ordinary Portland cement type-I conforming to BDS232-1974 or BS12.
- c) Reinforcing bars shall be deformed bars manufactured from billets conforming to BDS-1313, ASTM A615 or AASHTO M31.

d) Water to be used in concrete mix, as well as in slurry fluid shall meet the requirements of AASHTO T26.

B. Temporary metal case

Temporary metal case with wall thickness 10 mm (minimum) and diameter equal to the nominal diameter of pile, and a length of 2 m (minimum) shall be installed into the ground using bailer. The metal case should be free from dent or distortion.

C. Drilling of bore holes

The pile holes shall be bored by percussion or rotary drilling rigs with direct mud circulation method using bentonite slurry as drilling fluid. The least diameter at any section of bore hole should not be less than the nominal diameter of the pile. In percussion method, diameter of the chopping bail shall not be less than the diameter of pile by more than 75 mm. The borehole shall be filled with bentonite-slurry.

The slurry shall circulate continuously through drill rods and flow up along the sides of the boreholes with cuttings to the surface and be separated from the slurry by decantation for re-circulation. Bentonite has the property of remaining in suspension in water to form a stiff 'gel' when allowed to become static. When agitated by stirring or pumping, however, it has a mobile fluid consistency. In a granular soil, the slurry penetrates the walls of the bore-hole and gels there to form a strong and stable 'filter-cake'. In a clay soil there is no penetration of the slurry but the hydrostatic pressure of the fluid, which has a density of 1.04 g/l (65 lbs/cft.) prevents collapse where the soil is weakened by fissures.

For preparing the slurry, good quality bentonite (LL-250) shall be used and whenever the viscosity of slurry drops due to concentration of cuttings in the slurry, additional bentonite shall be added to maintain the requisite viscosity. Once the borehole is drilled down to the final depth, fresh slurry from reserve tank shall be pumped in for approximately fifteen minutes or more (depends on the diameter and depth of borehole) and be checked that the contaminated slurry is completely removed. The borehole shall be thoroughly cleaned and the cuttings from the base shall be removed.

D. Boring sequence

Pile holes shall not be bored close to the other piles which have recently been cast and which contains workable or unsettled concrete. This may induce flow of concrete causing damage to any of the piles. No drilling shall be allowed within a clear distance of 3m from a freshly concreted pile hole within 48 hours of time. Where there are more than four piles in a cluster, the center pile shall be installed first. All piles shall be drilled within a lateral tolerance of not more than 50 mm from the specified location.

E. Working platform

The pile hole shall be excavated from an elevation of 0.6m above its cut-off level to reduce the wastage of concrete in the form of "fresh concrete-overflow" and to place re-bar cage in right position.

In case, if the designed cut-off level is located beyond this depth, the top soil shall be excavated out before erection of pile rig. In places, where ground water level is high, pile shall be executed from higher elevations and "fresh concrete overflow" shall be maintained. Adequate measures shall be taken to place and uphold the re-bar cage.

The drilling of pile hole/pouring of tremie concrete shall be prohibited from a platform where the ground water is lowered by dewatering.

F. Stabilization of pile holes

Permanent steel lining shall be required in pile hole drilling through very soft cohesive and loose non-cohesive soil. Permanent steel lining may also be required in sub-rounded to rounded sand layers and also in sand with uniformity coefficient (D60/D10) less than 5. The drilling fluid level

within the temporary case shall be maintained around two metres above the adjacent ground water table. Suitable characteristics of drilling mud (viscosity and density) shall be determined from a trial pile hole. Higher density slurry shall be required in poorer soils. The upper limit of slurry density shall be 1.10 gm/cm³.

G. Fabrication and installation of reinforcement

The reinforcement cage for the pile shall be fabricated on the ground and shall be secured by means of galvanized iron wire in such a manner that it forms a rigid cage. The flat bar spacer (300mm x 37mm x 33mm), treated with non-corrosive paint spaced 1.5m intervals, three at each section shall be securely attached to the reinforcement to ensure the required concrete cover. Circular spacers shall never be permitted. The entire reinforcement cage assembly shall then be carefully lifted and lowered into the bore hole previously prepared to receive it. If it is required to lower the reinforcement cage assembly into the borehole in more than one section, the main longitudinal reinforcement shall be lapped for not less than 40 bar diameter and the tie shall be doubled over the laps. In addition, m.s. flatbar spacers shall be located immediately below and above the laps. The ties shall be welded to main bars in such a way that ties don't shift their position and several ties assemble at one position at the time of pouring concrete or lowering the cage.

H. Cleaning of pile holes

The final cleaning up operation before pouring concrete in a bored pile consists of removing large crumbs of soil or puddled clay from the pile base. This is done by pumping fresh slurry continuously from a reserve tank (lined) trough tremie. This will ensure clean pile hole and provide firm end bearing of pile. The pressure of slurry fluid during drilling in excess of 1.5 kg/cm² (20 psi) or jetting downward shall be avoided. The greater pressure of slurry jet will loosen the subsoil around the pile tip resulting a reduction of end bearing vis-a-vis load carrying capacity of the pile. The time interval between the final cleaning up and placing concrete should not exceed one hour. If there is any appreciable delay the depth to the pile bottom should be checked against the measured drilled depth before placing concrete to ensure that no soil has fallen into the hole.

I. A controlled concrete pouring operation is essential in achieving structurally sound piles.

The grade C25 concrete (compressive strength 25 N/mm²) with minimum cement content of 400 kg/m³ and high slump (125-150 mm) with well graded naturally available shingles ensure free flow and forms continuous monolithic concrete shaft. The efficient tremie diameter for underwater concrete pouring is 200 mm (minimum). The tremie assembly shall be straight and leak proof.

A satisfactory pouring and clean pile tip can be ensured by using disposable plug with tremie lowered within the borehole and keeping the tremie tip 150 mm above the borehole bottom. The first charge of concrete shall fill the tremie length plus twice the volume required to fill the space below the tremie tip. The tip of the tremie shall always be placed around 6 inch deep within the fluid concrete. In case the tremie is lifted accidentally above the level of concrete, the tremie shall be removed completely from the pile hole, cleaned and installed again with a new disposable plug within 150 mm of fluid concrete. The tremie filled with fresh concrete shall then be pushed around 2m below the concrete level in pile hole to continue the subsequent pouring operations.

The construction process, from the beginning of drilling or excavation to the completion of concrete pouring shall be uninterrupted and continuous.

The choice of right personnel is very important for the construction of piles. The common pile construction equipments comprising of a tripod set, power winch, mud pump, drill rods, circular chopping bits and tremie concrete pouring operations may be effectively used to construct sound vertical piles. This, however, needs services of qualified and experienced engineers, drilling foremen conversant with relevant geological formations.

4.6.2.3 Precast piles

Control of precast piles commences with the inspection and testing of the prefabricated piles before they are driven. Operation of casting precast concrete piles on site or in factory should be inspected regularly and cubes or cylinders of the concrete should be made regularly for compression test at the appropriate age. Materials used for concrete production should be tested for compliance with the

relevant standards. The piles should be clearly marked with a reference number, length and date of casting at or before the time of lifting to ensure that they are driven in the correct sequence.

If piles are driven to end bearing on hard stratum, it is necessary to record the sets in blows for each 25mm of penetration after the piles have reached the hard stratum. On the other hand when piles are supported in skin friction, say, in a stratum of firm to stiff clay or in a granular soil overlain by weak soils, it is essential to record for every pile the level at which the bearing stratum is encountered and hence to check that the required length of shaft to be supported by skin friction is obtained. For this purpose, the blows required for each 500mm or 250mm of penetration must be recorded over the full depth of driving of each pile, until the final metre or so, when the sets are recorded in blows for each 25mm. Sometimes the final sets are recorded as penetration depth for 10-25 blows on the hammer. The advantage of recording the full driving log for piles for every category is that, if trouble arises, such as pile breakage, the record of each pile can be scrutinized and any one which shows peculiarities can be singled out for special examination or testing.

At the preliminary piling stage the driving records are compared with the site investigation data and with the results of loading tests and suitable criteria.

Damages to the piles and deviation in alignment should be recorded which might indicate breakage below ground level.

The method of handling the piles after casting and transporting them to site is discussed below. The piles must be lifted from the stacking position only at the prescribed point. If designed to be lifted at the quarter or third points, they must not at any stage be allowed to do otherwise or to rest on the ground on their end or head. Particular care should be taken to avoid over-stressing by impact if piles are transported by road vehicles.

A helmet and its packings are carefully centered on the pile and the hammer position should be checked to ensure that it delivers a concentric blow. The hammer should preferably weigh not less than the pile. The weight and power of the hammer should be sufficient to ensure a final penetration of about 2.5 mm ($\frac{1}{10}$ in) per blow unless rock has been reached. Damage to the pile can be avoided by using the heavier hammer and limiting the strokes. Distress at the pile head is more likely to be the result of using hammer that is too light and hence needing an excessive drop than using a hammer that is too heavy.

Approximate minimum hammer size for driving R. C. C. bearing piles based on design load of pile for drop hammers are as follows (Fleming) :

Design load (kN)	Approximate minimum hammer mass (tonne)
400	2
600	3
800	4

The height of drop varies usually between 200mm to 2m. Normally 1m drop is considered suitable. Since the peak stress at the pile head can be greatly increased if the hammer strikes the pile eccentrically, a long narrow hammer is preferable, as there is more chance of the blow being axial and it has better impact characteristics.

Fig 4.1 shows the energy distribution during a precast reinforced concrete pile for various hammer weights.

The driving of the piles should be carefully watched and moving-off line should be eased. The drop of the hammer should be reduced if cracking occurs and if necessary the hammer should be changed for a heavier one.

After completion of driving the piles, the heads should be prepared for bonding into pile caps.

4.6.2.4 Positional Tolerance

It is impossible to install a pile, whether by driving, drilling or jacking, so that the head of the completed pile is always exactly in the intended position, or that the axis of the pile is truly

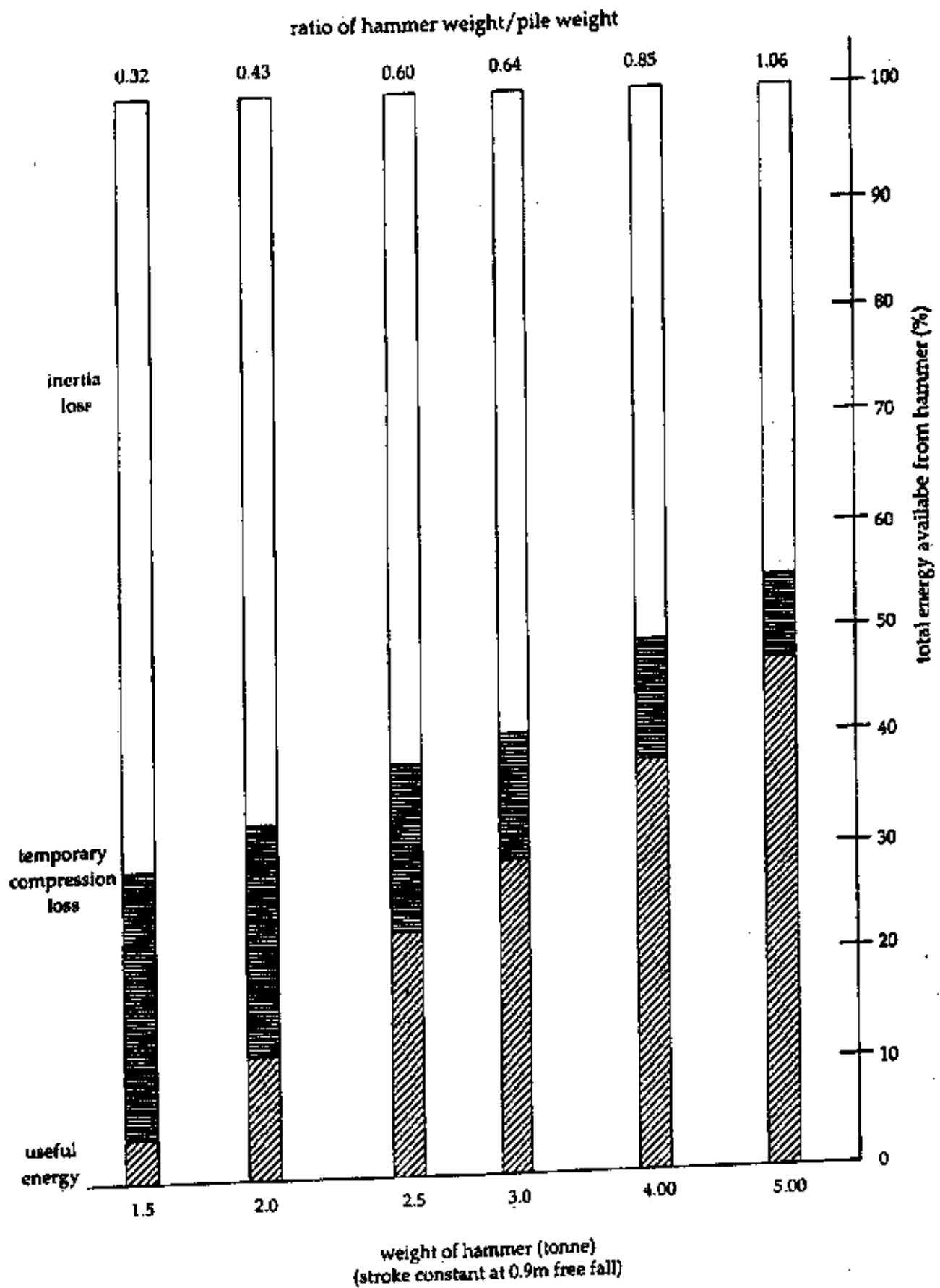


Fig. 4.1 Energy distribution during driving a precast reinforced concrete pile for various hammer weight (Fleming)

vertical or at the specified rake. Driven piles tend to move out of alignment during installation due to obstruction in the ground or the tilting of the piling frame leaders. Driving piles in groups can cause horizontal ground movements which deflect the piles. In case of bored piles, the auger can wander from the true position or the drilling rig may tilt due to the wheels of trucks sinking into soft ground. However, controlling the position of piles is necessary since misalignment affects the design of pile caps and ground beams and deviation from alignment may cause interference between adjacent piles in a group or dangerous concentration of load at the toe. Accordingly, code of practice specify tolerances in the position of pile heads or deviations from the vertical or intended rake. If these are exceeded, actions are necessary either to redesign the pile caps, as may be required or to install additional piles to keep the working loads within the allowable values.

The position of the pile head is to be within 75mm to 150mm (3 inch to 6 inch) for the normal usage of piles beneath a structural slab. The axis may deviate by upto 10% of the pile length for completely embedded vertical piles provided the pile axis is driven straight. For vertical piles extending over the ground surface the maximum deviation is 2% of the pile length, except that 4% deviation can be permitted if the resulting horizontal load can be taken by the pile cap structure.

4.6.2.5 Load test of piles

The ultimate load carrying capacity of a single pile may be determined with reasonable accuracy from test loading. The load test on a pile shall not be carried out earlier than four weeks from the time of casting the pile.

Two principal types of test may be used for compression loading on piles. These are :

- a) The constant rate of penetration (CRP)
- b) Maintained load (ML)

In CRP the compressive load is progressively increased to cause the pile to penetrate the soil at a constant rate until failure occurs. In the second method, the load is increased in stages to some multiple, say 1.5 times or twice the working load with the time settlement curve recorded at each stage of loading and unloading. The ML test may also be taken to failure by progressively increasing the load in stages.

The CRP method is essentially a test to determine the ultimate load on a pile and is, therefore, applied only to preliminary test piles or research type investigation.

In CRP test the recommended rates of penetration is 0.75mm/min. for friction piles in clay and 1.55mm/min for piles end bearing in granular soil. The CRP test shall not be used for checking the compliance with specification requirements for the maximum settlement at given stages of loading.

The ML test is best suited for proof loading tests on working piles. The load at each stage is held for a minimum period of 1 hour or beyond this period if the rate of settlement has not decreased to less than 0.1 mm in 20 minutes and is still decreasing.

An accepted system of loading increment for an ML test upto 1.5 times the working load is as follows :

Load as percentage of working load	Minimum time of holding load
25	1 hour
50	1 hour
75	1 hour
100	1 hour
100	1 hour
75	10 minutes
50	10 minutes
25	10 minutes
0	1 hour
100	6 hours
125	1 hour
150	6 hours
125	10 minutes
100	10 minutes
75	10 minutes
50	10 minutes
25	10 minutes
0	1 hour

Load test arrangements as specified in other standard practice such as ASTM may also be followed.

If it is desired to obtain the ultimate load on a preliminary test pile, it is useful to adopt ML method for upto twice the working load and then to continue loading to failure at a constant rate of penetration.

CRP and ML test use the same type of loading arrangement and pile penetration. A square cap is cast onto the head of the concrete pile with its underside clear of the ground surface. Suitable loading arrangements for applying the loads are then made.

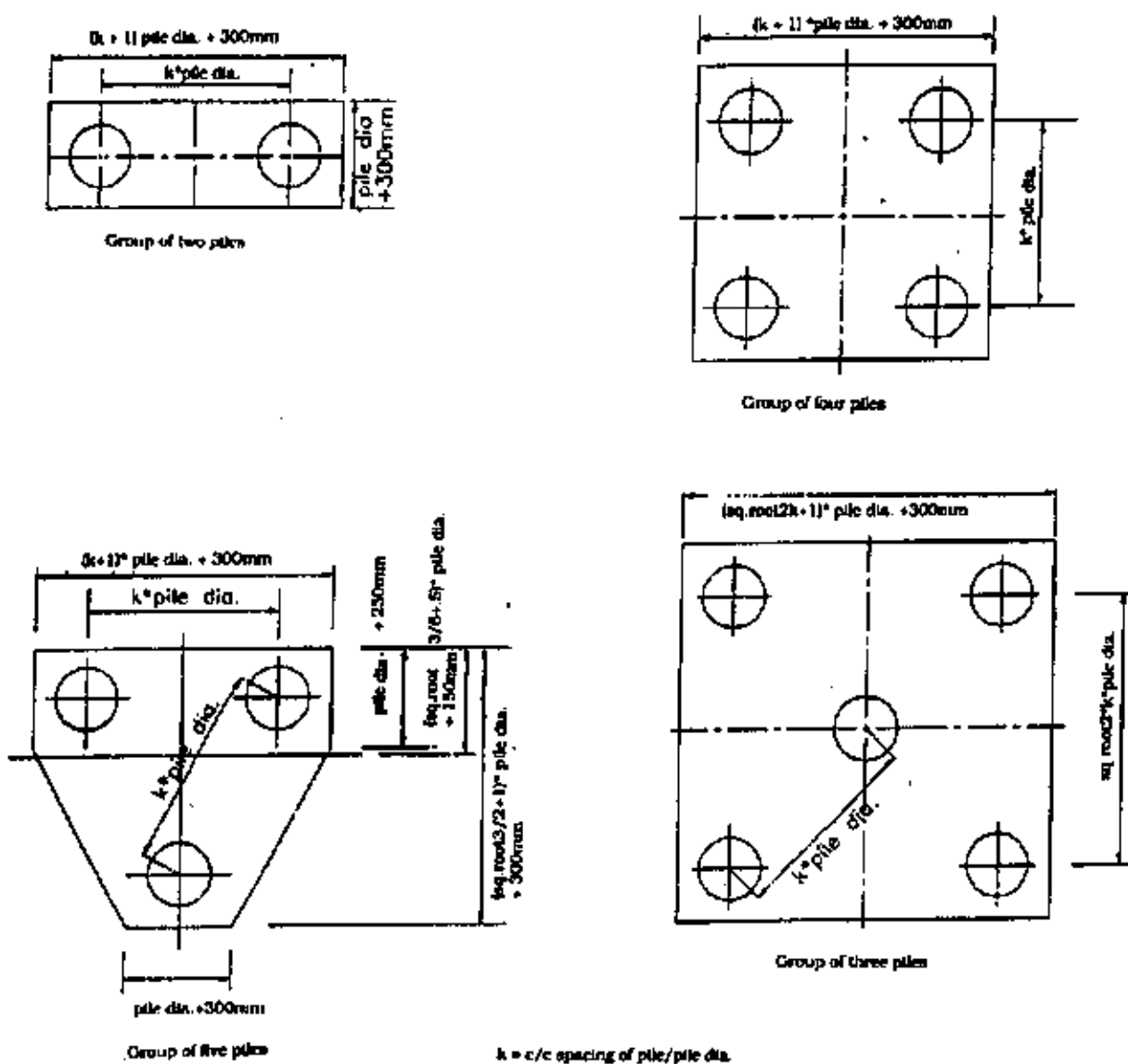


Fig. 4.2 Standard pile caps

Ref. Pile Design and Construction Practice
by : M. J. Tomlinson

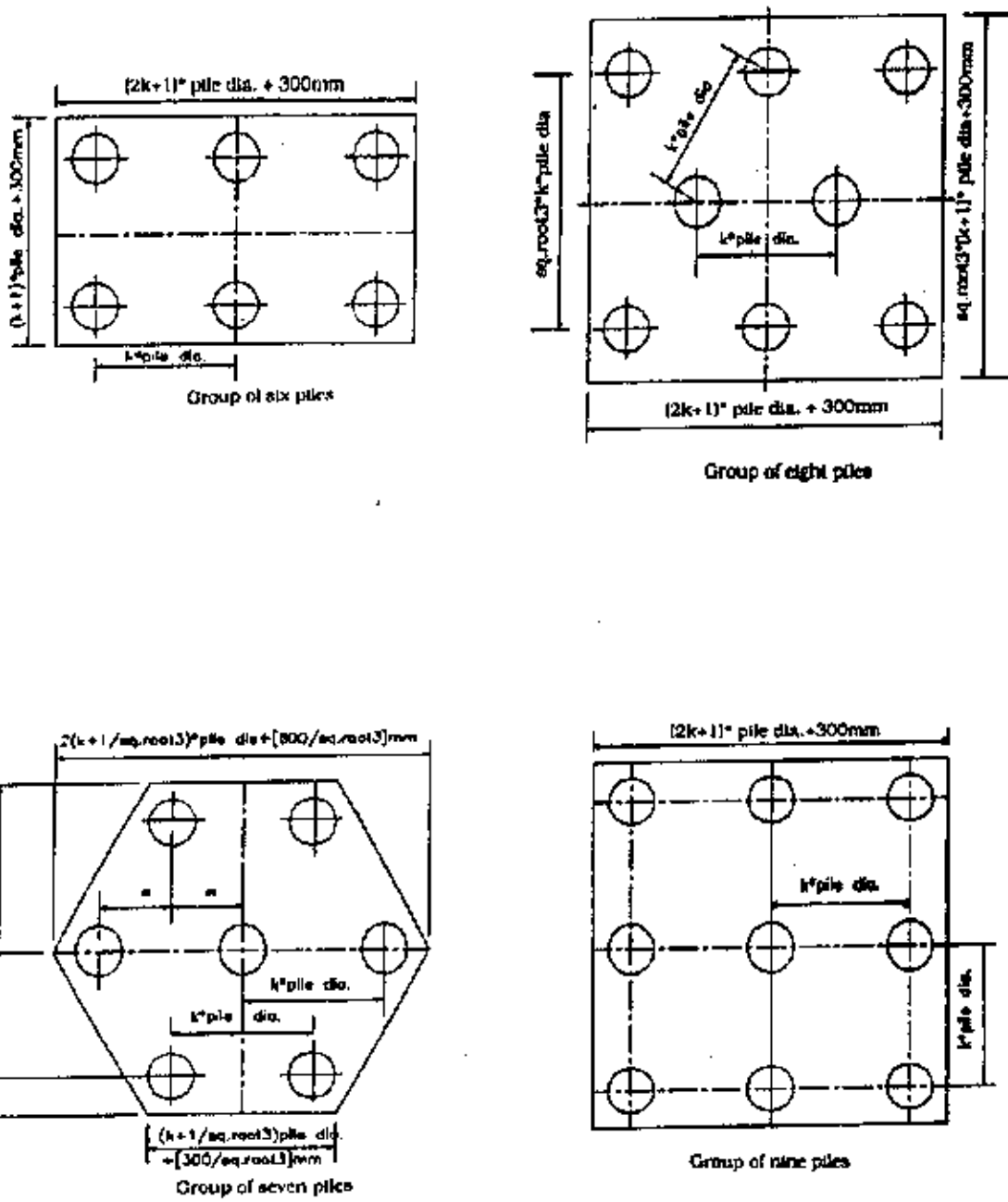


Fig. 4.3 Standard pile caps

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4.6.2.6 Concluding Remarks

It should be remembered that pile foundation is a highly technical job and needs special technique, skill and endurance. As such though sectional officer is primarily responsible for general supervision and measurement of works, the Executive Engineer, Sub-Divisional Engineer/Assistant Engineer should take personal responsibility for the execution of pile driving. It must not be left with sectional officer to supervise. They should make adequate arrangements and establish sufficient checks for the purpose. A graduate Engineer shall be engaged full time to supervise the work and Sub-Divisional Engineer and Executive Engineer shall sign all records and ensure that the work has been executed as per plan and design.

4.7 FOUNDATION ON EXPANSIVE SOIL

Soils which undergo volume changes upon wetting and drying are termed as expansive soil. This soil is found in many parts of Bangladesh and contain large amount of clay. These soil expands during rainy season. Due to the swelling of the soil great pressure is exerted upon the foundation and cracks develop in the walls. These cracks are predominant around corners.

The following precaution may be considered while placing foundation on expansive soil.

- a) Alter the soil : For example addition of lime, cement or other admixture will reduce or eliminate the volume change on wetting and drying.
- b) Control the water : The soil may be excavated to a depth such that the weight of the soil will control heave, lay a plastic membrane and then back fill. The rising water vapour is collected at a depth such that volume change is controlled by the weight of the overlying materials and construction. The moisture above will also have to be controlled by paving, grading.
- c) Ignore the heave : By placing the footing at sufficient depth and/or leaving an expansion zone between the ground surface and the building, swell can take place without causing detrimental movement. Sometimes the pier shaft is surrounded by porous materials to reduce adhesion.
- d) Load the soil to sufficient pressure intensity to balance soil pressure: This method is used in many fills where the fill weight balances the soil pressure. This can also be used beneath buildings either by using spread footing of high pressure intensity or excavating several feet of clay and backfilling with granular backfill. This combined with foundation pressure may contain swell. This method may not be practical for one storey building and residences because of the small soil pressure developed.

In no case brick foundation should be provided in expansive soil and the base of foundation for important buildings should be placed at sufficient depth so that the effect of swelling can be avoided.

4.8 EFFECT OF WEATHER CHANGES

As fast growing trees absorb moisture from the soil, thus affecting the structure of the soil, it is desirable that these types of trees should be at least 50'-0" away from important buildings. The distance will also help in keeping the tree roots away from the building foundation and keep the roof of the building free from dripping of the rain water from the tree leaves.

The foundation should be kept free from the damage by the surface water or drainage water entering alongside the plinth wall. Surface drain with apron or simply aprons should be made to protect the foundation. At least compacted earth with a slope outward instead of a pucca apron should be provided for protection of the foundation. In case where the entire site cannot be raised above HFL for particular reason, earth filling should be extended at least upto 10'-0" from plinth wall to keep the flood water or rain water at a safe distance from the building.

4.9 RETAINING WALL

General description

Retaining wall may be defined as a structure constructed to hold back masses of earth or other loose materials where conditions make it impossible to let those masses assume their natural slopes.

Retaining walls provide soil stability at a change in ground elevation. Such conditions occur when the width of an excavation, cut or embankment is restricted by conditions of ownership, use of the structure or economy. One example is the basement wall of a building which must be located within the property and must retain the soil surrounding the basement. Sometimes retaining walls are constructed to prevent erosion or rain cut of soil to save buildings and structures.

Retaining walls may be of masonry wall, plain or reinforced concrete. Plain concrete retaining walls shall act as gravity retaining walls like masonry retaining walls.

4.9.2 Types of retaining walls.

There may be several types of retaining wall as follows :

a) Gravity walls

Gravity retaining wall depends entirely on its own weight for stability. They are usually low in height. Gravity retaining walls are normally constructed with brick masonry which is a cheap construction material. But after certain height say about 10'-0", it becomes expensive because of huge mass of masonry work that is needed to attain stability.

b) Cantilever retaining wall

A cantilever retaining wall is a reinforced concrete wall that utilizes the weight of the soil itself to provide the desired weight for stability, but the wall's resistance to collapse depends upon the strength of its individual parts. Stem, Toe and Heel are each designed as cantilever slabs.

There are three types of cantilever retaining walls :

- 1) T-shaped wall
- 2) L-shaped wall
- 3) Reverse L-shaped wall

An upside down "T-shaped" cantilever retaining wall is the most simple and common type of retaining wall.

An "L-shaped" cantilever retaining wall is used when the wall is along a property line or in other situations where a toe can not be provided. Its disadvantages are excessive pressure at the front edge and difficulty is resisting the bending moment at the junction between the stem and the heel.

It is usually difficult to make a "reverse L-shaped" retaining wall stable and to keep it from sliding if the height is great, because of the fact that the dead load is relatively small. However, such walls are useful in cases where it is expensive or impossible to provide a heel. A cantilever retaining wall is economical for heights between 10'-0" to 20'-0" .

c) Counterfort retaining wall.

A counterfort retaining wall is a modification of T or L shaped cantilever retaining walls. It has intermittent vertical ribs called counterforts. A counterfort retaining wall like cantilever retaining wall uses the weight of soil for its stability. The wall and base are tied together at intervals by counterforts or bracing walls. These act as tension ties and totally change the supports for stem and heel slabs. The stem becomes a slab spanning horizontally between counterforts and the heel becomes a slab supported on three sides. Counterfort is advantageous for very high wall because the counterforts can be heavily reinforced so as to act as ties to connect stem and heel, so that the stem and heel can be relatively thin.

This type of retaining wall becomes more economical than the cantilever type when the height is in the range of 20'-0" to 25'-0" .

Which of the three types of walls discussed above is appropriate in a given case depends on a variety of conditions, such as local availability and price of construction materials and property rights.

d) Butressed wall

A butressed wall is similar to the counterfort wall except that the bracing members are on the opposite side of the wall and act in compression.

There are other types of retaining walls like bridge abutments, box culvert etc. which have not been considered in the purview of this book.

4.10 BASIC DESIGN CONSIDERATIONS OF RETAINING WALLS

a) The design of a retaining wall shall require that it should be so constructed that :

- i) It will not overturn about the front of its toe.
- ii) The soil pressure under the toe will not exceed the allowable bearing pressure on soil.
- iii) The wall will not slide outward bodily due to thrust, that is, the wall as a whole may not be bodily displaced by the earth pressure.
- iv) The component of the retaining wall will not rupture. The individual parts will be strong enough to resist the acting forces.

b) Overturning

The forces acting on any wall are the horizontal thrusts of the materials retained and the vertical load which is the sum of the weight of the wall and all other vertical loads. In order that, there is no danger of overturning, the line of resultant of these two forces should pass within the middle third of the base of the wall.

c) Bearing pressure

The base width of the wall should be sufficient to keep the soil pressure under toe within safe permissible limits.

d) Sliding

Due to the earth pressure the wall will have a tendency to slide. This tendency of the wall to slide is checked by two ways.

- i) By friction between the base concrete and soil below
- ii) By the direct compressive resistance of the soil in front of the toe wall

If the total horizontal thrust is not more than half the weight of the wall, the frictional resistance along is sufficient to prevent sliding. Sometimes a key is provided in the heel slab to increase resistance against sliding.

The passive resistance of the soil in front of the structure may have considerable abutting power, but the wall should stand without depending upon this force. Absence of earth in front of the wall when the backfill is placed behind the structure, thoughtless excavation of earth along the toe by someone in the future, possible scouring and washing away of this material - all these are reasons for this statement. Sometimes this passive resistance is relied upon, but this should be done with caution.

e) Stability of the components

To design against the rupture of individual components, it requires the determination of the necessary dimensions, thickness, reinforcement etc. to resist the moments and shears. This procedure is in no way different from that of determining the required dimensions and reinforcements of other types of concrete structures.

A retaining wall needs weight in order to resist overturning and sliding. Therefore, it is not usually advisable to use high strength concrete and excessively thin concrete section for ordinary wall because they are light in weight.

4.11 SAFETY FACTOR

The stability of a retaining wall is its ability to hold its position and to perform its function safely. The safety factor is a measure of the magnitude of the forces that are required to cause failure of the structure, compared with the forces that are really acting upon it. Thus if the safety factor is 1, the wall will be upon the point of failure. If for any given design, it is 2, then the overturning moment or the horizontal forces may be doubled before the wall will fail. The magnitude of the safety factor to be used in a design will depend upon the Engineer's judgement, the specification or the building code that is to be followed.

In general, it may vary from 1.5 to 2 for overturning and 3 for bearing pressure.

4.12 FACTORS AFFECTING ACTIVE PRESSURE

The factors that may affect the active pressure on a wall are as follows:

1. Type of fill.
2. Seasonal condition of the back fill materials such as wet, dry.
3. Drainage of back fill materials.
4. Possibility of back fill overload such as trucks, equipments near the wall.
5. Degree of care exercised in back filling.
6. Possibility of vibration in the vicinity of the wall (specially in the case of granular soil).
7. Type of materials beneath the footing of the retaining structure.
8. Level of water table.

4.13 APPROXIMATE SIZE OF COMPONENTS OF CANTILEVER RETAINING WALLS.

- a) Base width: A base width shall be as narrow as possible for economy yet sufficiently wide for stability against overturning. The approximate value may vary from 0.4 to 0.6 times the overall height of the wall, if there is no surcharge. For fairly inclined surcharge it may be upto 0.70 times the overall height of the wall.
- b) Thickness of the base : The base thickness is generally about 1/10th of the total height of the wall with a minimum of 1'-0". It should be equal to the base thickness of the stem.
- c) Thickness of the stem : The thickness at top of the wall is arbitrary, however, covering requirements and construction constraints will dictate how thin it may be. Generally 10 or 12 inch minimum is preferred, though no minimum is prescribed by ACI. The base thickness of the stem is determined as required for bending moment and shear, though it may be estimated as 12-16% of the base width, or 10% to 12% of the wall height or $\frac{1}{2}$ in. per foot height plus the top thickness or slightly more.
- d) Toe length: The projection of the toe beyond the edge of the vertical stem is taken to be $\frac{1}{4}$ th to $\frac{1}{3}$ rd of the base width.

The optimum design of any retaining wall is a matter of successive approximation. Reasonable dimensions are assumed by experience and various conditions of stability are checked for these dimensions. On the basis of first trial, dimensions are readjusted and one or two additional trials usually result in a favourable design.

4.14 DESIGN STEPS OF RETAINING WALL

a) Cantilever

- i) Choose tentative proportion for the wall and fix the thickness of stem by calculating moment at the junction of the base slab and the stem.
- ii) Estimate the magnitude of all pressure on the entire height of the wall and check the safety of the wall against overturning.

- iv) Check the resistance of the wall to sliding and provide a key wall, if necessary.
- v) Determine the magnitude of the foundation pressure against the base and check for the maximum pressure on the base.
- vi) Calculate the reinforcement in the stem.
- vii) Calculate the pressure and moment on toe and fix the thickness and reinforcement required; check for shear.
- viii) Calculate the pressure and moment on the heel and fix the thickness and reinforcement required.

b) Counterfort

- i) **Stem:** It is designed as a continuous vertical slab spanning over counterforts. Since the thrust due to earth pressure which is also the load per unit height of wall, for which the stem is designed, varies with the depth below the surface level, the bending moment in the slab varies accordingly. It shows that maximum bending moment in the stem shall occur at its junction with the base slab and decreases proportionately at various depths. The thickness of the wall slab is calculated for the maximum bending moment and the thickness should be kept uniform throughout and only the reinforcement should be varied at various heights.
- ii) **The base slab:** The heel is designed as a horizontal slab supporting the counterforts and subjected to bending moment induced by the back fill and the sub soil reaction due to loading. The toe of the counterfort wall is subjected to a net upward pressure. It is designed exactly in the same manner as cantilever retaining wall.
- iii) **Counterforts:** The earth pressure acting on the stem is transferred to the counterforts. The total load to which each counterfort is subjected is the total pressure per unit height of stem multiplied the C/C spacing of the counterforts.

Thus the back of the counterfort is in tension. It is designed as a cantilever of non-uniform depth fixed at the top of the base slab. The effective depth of the counterfort is measured at right angle to its sloping side. Tensile reinforcement is provided along the sloping face and is efficiently anchored at both ends.

Since the stem has a tendency to pull away from the face of the counterfort, horizontal ties must be provided to tie the stem with the counterfort. Similarly the base slab has also the tendency of pulling away from the bottom of the counterforts, the two must be tied by means of vertical ties.

c) Gravity

A gravity retaining wall depends mostly upon its own weight for stability. So for a gravity retaining wall the resultant of the weight of wall with the soil upon it and the total thrust of the earth should remain within the middle third of the base of the wall. The bearing pressure of the soil upon which the wall is constructed should be well within the allowable limit.

Safety factor against sliding should also be checked which should be at least 1.5.

4.15 BACK FILL

The character of materials used for back fill has an important influence on the forces acting against the inner face of the retaining wall. Non-cohesive soil like clean sand are considered superior to all other soils, because they are free draining and do not become less stable with the passing of time. Silty sand, silts or granular soils containing a small percentage of clay are less desirable, because they can not be drained readily and may experience a decrease of shear strength with accumulation of moisture. Clays are undesirable as back fill because they can hardly be drained, are likely to experience alternate swelling and shrinkage with the seasons and may loose much of its shearing strength if moisture accumulates. If shrinkage cracks in a clay backfill become filled with rain water, the wall may be subjected to full hydrostatic pressure as well as earth pressure, even if

drains have been provided. As such it is strongly advised to avoid clay as backfill for retaining wall.

The ground surface shall be prepared to receive fill by removing vegetation, non-complying fill, top soil and other unsuitable materials. Detrimental amount of organic materials shall not be permitted in fills. Back fill shall be placed in layers of 12 inch. Cohesive fills should be compacted with a mechanical tamper to secure a density not less than 90 percent of the maximum density. Compacted soil reduces the void ratio and thereby decreases the settlement of a fill. It also reduces the permeability which is of great importance when the soil is cohesive, because the tendency is reduced for water to penetrate the backfill and thereby decrease its shearing strength and stability.

A designer does not often have sufficient information concerning the significant properties of soil to be used as backfill, for a wall he is designing. Under these conditions, he must make assumptions which appear to be reasonable. It is, therefore, important that, either the significant properties of back fill are supplied to the designer before the design work or the supervising Engineer exercises his judgement in approving back fill materials to be familiar with the factors which determine the suitability of such materials.

4.16 METHOD OF CONSTRUCTION

Construction method of retaining walls is similar to other structures, but precautions should be taken as stated in section. 4.17

The lumber used for formwork for walls of retaining walls should be strong, sustainable and unyielding. They should be water tight so that mortar does not leak out. Bracing and propping should be strong enough to carry the lateral pressure of the liquid concrete.

Vibration or other methods of compaction should be conducted.

Full height of the wall should be poured in a continuous process. If one pour is allowed to set for several days, considerable heating and expansion will occur initially, cooling and shrinkage will then follow. When another pour is placed on the top of the first one, the former is in its warmer and expanded condition as it sets. Then when it tries to shrink, the lower pour tends to prevent this shrinkage and to cause crack in the upper lift. Therefore, it is advisable to pour full height by increments that are added at intervals of few hours in order to have each pour placed, the one under it has not set too long and shrunk too much.

Cleaning of horizontal joints is slow and difficult. Continuous but slow pouring will often minimise or eliminate such cleaning.

When one pour is made on top of a lower one from which the forms have been removed special care is needed to prevent leakage of mortar where the upper form rests upon. Mortaring the junction may serve as remedy against the difficulty.

All reinforcement work has to be completed before the forms are erected. After the forms are set, all debris, dirt or other materials should be removed.

Removal of forms may be troublesome unless this operation is planned in time. Oiling the inside of forms or coating them with some other suitable materials will help to avoid bond between the form and the concrete. Adequate cleaning of a used form is essential prior to its reuse.

The position and details of the form should be carefully checked before any concrete is poured in them. The surfaces of timber shuttering that are to come in contact with concrete should be well wetted with water. This is necessary to prevent the chances of dry shuttering timber absorbing water from the concrete which may cause warping, swelling and distortion of timber besides resulting in defect of honeycombing in concrete.

The base slab may be poured on brick flat soling covered with polythene sheet to avoid leakage of mortar.

The back of the retaining wall should be damp proofed by a suitable damp proofing materials.

Special care should be taken so that the clear cover as described in the design sheet is maintained, both inside and out side face of the retaining wall.

4.17 PRECAUTIONS

It is very important to find all walls upon undisturbed soil. The consolidation that has been produced by nature has probably given the soil the best treatment that it can have for use as an ordinary foundation. In no case a wall be placed upon newly deposited fill when avoidance of settlement is important.

Allowable bearing pressure should be selected with great care. It is necessary, for this purpose, to investigate not only the type of soil immediately underlying the footing, but also the deeper layers. Unless reliable information is available at the site, sub-surface boring should be made to a depth equal to at least the height of the wall. The foundation must be laid below vegetation layer, which amounts to 4' to 5' from existing ground level.

An increase of moisture in the earthen mass retained by the wall increase the horizontal thrust. Ample provision should, therefore, be made for drainage. Drainage can be provided in various ways. Weep holes consisting of 4 inch pipes embedded in the wall at the bottom of the stem with a slope outward are usually spaced horizontally 5' to 10' apart. In addition to bottom row, additional rows 5'-0" C/C should be provided in walls. To facilitate drainage and prevent clogging, 1' or more of crushed stone is placed at the rear end of each weeper. Care must be taken that the outflow from weep holes is carried off safely so as not to seep into and soften the soil underneath the wall. To prevent this instead of weepers, longitudinal drains embedded in crushed stone or gravel can be provided along the rear face of the wall at one or more levels, the drains discharging at the ends of the wall or at a few intermediate points. The most efficient drainage is provided by a continuous back drain consisting of a layer of gravel or crushed stone covering the entire rear face of the wall with discharge at the ends. Such drainage may be expensive unless appropriate material is cheaply available at site.

In long walls provisions must be made against damage caused by expansion or contraction from temperature changes and shrinkage. Vertical expansion joints should be provided at every 60 - 80 ft.

Expansive types of soil which expands under increasing moisture content should not be used as backfill behind retaining wall.

The wall should be cast in short lengths, not to exceed 30-40 ft. to reduce shrinkage stress.

After the construction is over, care should be taken to avoid heaving of the bottom and side of the toe, erosion or displacement of passive earth over the toe, proper slope and turfing should be maintained to avoid scouring.

Rollers should not be used for compacting soil close to the retaining wall because of the temporary increase caused by the weight of the heavy equipment.

4.18 WATERPROOFING AND DAMPPROOFING

Wall and portions thereof that retain earth and enclosed interior spaces and floors below grade shall be waterproofed and dampproofed with the exception of those spaces where such omission is not detrimental to the building or occupancy. The engineer shall perform sub-surface investigation to determine the possibility of the ground water table rising above the floor below grade.

Two such situations may arise :

- i) where no hydrostatic pressure occurs
- ii) where hydrostatic pressure occurs.

Where hydrostatic pressure conditions exists, floors and walls below finished ground level shall be waterproofed. Where hydrostatic pressure conditions do not exist, damp-proofing and perimeter drainage shall be provided.

4.18.1 **Waterproofing where hydrostatic pressure occurs :** Where ground water investigation indicates that hydrostatic pressure condition exists, or is likely to occur, walls and floors shall be waterproofed as follows :

- i) **Floor waterproofing :** Floors required to be waterproofed shall be of concrete and shall be designed and constructed to withstand the anticipated hydrostatic pressure.

Waterproofing of the floor shall be accomplished by placing under the slab a membrane of rubberized asphalt, or butyl rubber or polymer modified asphalt or neoprene or not less than 0.15mm polyvinyl chloride or polyethylene or other approved materials, capable of bridging non-structural cracks. Joints in the membrane shall be lapped not less than 150mm and sealed in an approved manner.

- ii) **Walls waterproofing**

Walls required to be waterproofed shall be of concrete or masonry designed to withstand the anticipated hydrostatic pressure and other lateral loads. Prior to the application of waterproofing materials on concrete walls, all holes and recesses resulting from the removal of form ties shall be sealed with a bituminous materials or other approved method or materials. Unit masonry walls shall be pargeted on the exterior surface below ground level with not less than 10mm of mortar. The pargeting shall continue to the foundation.

Waterproofing shall be applied from a point 300mm above the maximum elevation of ground water table down to the top of the spread portion of the foundation. The remainder of the wall upto a level not less than 150mm above finished grade by installing damp-proofing materials on the exterior surface.

Wall damp-proofing materials shall consist of two-ply hot mopped felts, not less than 0.15mm polyvinyl chloride, 1.0mm polymer modified asphalt, 0.15mm polyethylene or other approved methods or materials capable of bridging non-structural cracks. Joints in the membranes shall be lapped not less than 150mm and sealed in a approved manner.

EXCAVATION OF FOUNDATION TRENCHES

5.1 SCOPE OF WORK

The work covered by this item consists of earthwork in excavation in all types of soil upto a depth of 1.5m or more and in removing the spoil to a safe distance upto a lead not exceeding 50m.

The item covers earthwork in excavation for all types of structures such as buildings of all types, roads, airfields, parade grounds, ponds, reservoirs, canals, drains, underground structures etc.

5.2 METHOD OF CONSTRUCTION

Before commencing foundation work, the site shall be cleaned of all types of grass, weeds, shrubs, jungles, trees of upto 6" diameter and their roots. Trees are to be cut, sized and stacked properly at a suitable place as directed by Engineer-in-charge. The whole area shall be roughly levelled and all holes carefully filled up with sand or rammed earth and levelled off as required.

Permanent Bench mark is to be set at a suitable point at the site at a distance of 3m outside the area of excavation by constructing a 25.4 cm x 25.4 cm Brick Pillar. Proposed GL and PL of the proposed building shall be judiciously fixed and marked on the pillar as per drawing and direction. Proposed G.L. and P.L. shall be fixed with respect to highest flood level of the area as well as plinth of other buildings or the major roads in the area.

Layout of the proposed construction shall be set on the ground following the foundation plan of the structural design and read in conjunction with Architectural Plan. The centre lines shall be set out accurately by means of a theodolite for big structure and by any other approved method for other structures.

Brick pillars shall be constructed showing centre lines of walls, columns etc. at a distance of 3m from the outer edge of the trenches. No work shall be started till the layout is checked and approved by the Engineer-in-charge. Masonry pillars shall be 25.4 cm x 25.4 cm in size with 50cm above ground level and necessary foundation and shall be constructed with 1:6 cement sand mortar using first class bricks and the top shall be smooth finished.

Trenches shall be marked on the ground with chalk powder and be allowed to be checked by the Engineer-in-charge.

Excavation shall be made to the specified depth and width of the foundation as shown on the structural drawing. While excavating the trench, the last 75mm (3") of the excavation shall be left unexcavated initially. This depth should be dug out carefully in the final dressing after checking the level. The bottom of the foundation must be perfectly levelled longitudinally & transversely. All foundation trenches must be taken down to firm hard soil. If any soft or weak spot in foundation bed is observed, this should be reported to Engineer-in-charge for necessary instruction.

All earth excavated shall be removed outside the site to a lead not exceeding 50 metre.

The depth and width of the excavation may be increased or decreased by the Engineer-in-charge to meet the requirement of the Architectural plan or structural design.

Shoring, sheeting or bracing of the sides of the trenches must be done strongly, if required.

Arrangement for de-watering with water pump must be made, when required. The dewatering system shall include superficial pumping and drainage.

Protective measures shall be taken to prevent damage to adjoining structures, land, under ground service lines etc. caused by vibration, moving equipment or any action connected with earthwork in excavation failing which the contractor shall pay the damages or restore it to its original position.

No material excavated from the foundation trenches shall be placed nearer than 1m from the edge of foundation. Surplus of the excavated soil left after back filling of the trenches shall be suitably spread on the work site or be removed to a distance as directed by Engineer-in-charge.

5.3 PRECAUTIONS

Earthwork in excavation shall not be commenced before the pillars marking the centre lines and B.M. bearing known levels are checked by the Engineer-in-charge.

All loose materials and residue of foreign materials shall be removed before concrete casting is commenced.

In case if any utility service line is found to lie in the trench, the lines shall be protected from injuries or damages due to strikes from excavation tools. Immediate attention of the Engineer-in-charge shall be drawn to the presence of utility lines and measures shall be taken by the contractor without additional cost, to support them till the works below ground are completed.

Site Engineer shall inspect to confirm that the foundation bed has a uniform bearing capacity and there is no loose spot. If there is any loose spot, the area shall be specially treated in consultation with the designer.

Special care shall be taken to retain the sides of the foundation trench from falling and thus, filling the trench.

Excavation of trenches should be taken up only after receipt of detail structural drawings for the foundation.

BRICK SOLING IN FOUNDATION

6.1 SCOPE

The work covered by this item consists of brick flat soling on all types of soil at any depth with 1st class brick.

The item consists of a single layer of brick flat soling at the bottom of foundation trenches, floors, roads, pavements, drains and all other underground structures etc.

6.2 METHOD OF CONSTRUCTION

1st class bricks are only to be used in the work. The specification of brick shall conform to specification described in section 1.2.

The bed must be prepared level and compacted and dewatered and cleared of all loose materials. The bricks shall be laid flat as close as possible to each other and the joints broken.

The joints between bricks are to be filled in with sand of min. F.M.O.S. so as to stop any movement of the brick in any direction.

Herring bone bond soling shall be same as Sl.6.2 above except that the soling will be laid on side edge of the brick.

Brick on end edging shall be same as Sl.6.2 above except that the brick will be laid on end edge of the brick.

MASS CONCRETE IN FOUNDATION

7.1 SCOPE

Unless stated otherwise the item shall consist of preparing and pouring of cement concrete in proportion 1:3:6 in foundation trenches in all types of soil at any depth.

7.2 MATERIALS

Coarse aggregate shall be picked jhama brick chips graded from 6 mm to 20 mm of approved quality. The chips should be obtained by breaking well burnt picked jhama bricks/bats on a clear pucca platform. The aggregate should be free from all kinds of dust, leaves, grass, earth or any other organic materials. It should be properly screened by screen of specified meshes to remove the brick dust and particles smaller than 6 mm. For cleaning of the surfaces having clay or dirt, the brick khoa must be washed with water on the preceding day of its use.

Fine aggregate i.e. sand should have a minimum fineness modulus (F.M) of 1.2, properly screened and washed to free it from clay lumps, organic materials, salts etc.

Cement shall be ordinary Portland cement. It should be free from cakes. Cement should not have set in any way before use. Cement should be tested before use and test results shall be approved by the Engineer-in-charge.

Water used for mixing shall be clean potable water free from harmful chemicals and salts.

7.3 METHOD OF CONSTRUCTION

The concrete should be mixed in such a quantity as can be used in about half an hour. The fine and coarse aggregates shall be measured in standard measuring boxes. The batch boxes should be of such size as to contain the exact quantity of the dry aggregates required for mixing one bag of cement.

In case of hand mixing the coarse aggregate shall be measured by measuring boxes and stacked on a clean and smooth water tight platform large enough to allow efficient handling of the ingredients. Another stack of sand measured as above should also be placed on the mixing platform. The required quantity of cement is to be added over the stack of sand with uniform thickness and the whole mixed dry 2/3 times thoroughly to bring it to a uniform colour. This mixture of sand and cement shall then be placed over the stacks of coarse aggregate and thoroughly mixed dry at least thrice by means of spade with a little jerk added to it while cutting and spreading the mixture. The required quantity of water is to be added gradually to one side of the dry mix. The process of turning over is to be continued by backward and forward pushes of the spade. The entire mass is to be turned over at least three times until a homogeneous mixture of the required consistency is obtained.

7.4 MACHINE MIXING

When the mixing of the ingredients are done in a Mixing Machine half of the required quantity of aggregates for one bag of cement is placed on the hopper of the Mixing Machine. Cement is then placed over it and last of all the other half of aggregates is added to it. The requisite quantity of water is then gradually added, as the drum is rotated. The speed of rotation of the drum shall not exceed that prescribed by the manufacturer. The mixing is continued until proper consistency is attained. The quantity of water should first be ascertained by trials and then by slump test. The duration of the rotation shall not be less than two minutes. To determine whether the required consistency has been attained, slump test should be undertaken and the slump must not be more than that specified by the Engineer-in-charge. Excess water shall, on no account, be used as this weakens the concrete.

7.5 PLACING OF CONCRETE

Concrete shall be deposited in place without segregation and without disturbing the uniformity of the mix. The concrete shall in no case be dropped from a height greater than 600 mm. Gaps if purposely left in the brick soling, as per design, must be filled in with concrete. The concreting shall be carried on at such rate that the concrete is at all times plastic and flows easily into all spaces inside the forms. All concrete shall be thoroughly compacted by rodding with M.S. Rods $\frac{5}{8}$ " and higher dia. In addition, trowels shall also be used to compact the concrete near the surface of the form. During the operation of placing, concrete shall be thrown into corners and edges of the forms. While the concrete is still plastic it shall also be slightly rammed by flat bottom rammer until a thin film of mortar comes up to the surface. The finished surface shall be properly smoothed and levelled as specified. For compaction of concrete, wooden or steel tampers or rammers may be used instead of vibrator.

In order to improve bond with masonry/concrete work coming above it, if required, the surface shall be roughened before it reaches initial set, by securing with the help of a pointed tool.

7.6 CURING

As soon as the cement concrete has hardened sufficiently within few hours of casting it shall be covered with canvas or mats in order to protect it from the strong sun or dry wind. After 24 hours, it shall be covered with empty gunny bags and kept constantly wet by watering for at least 3 days.

7.7 PRECAUTION

Before the laying of concrete in foundation is started the brick soling below shall be sprinkled with water, so that no loss of water from the concrete can occur due to the absorption of water by dry bricks.

In case subsoil water tends to rise and wash away the foundation concrete while this is being done, de-watering of the foundation bed should be done from sumps by using pump or by manual labour. The de-watering should continue until the concrete has set.

BRICK WORK IN FOUNDATION AND PLINTH

8.1 SCOPE

The work covered by this item consists of the constructing brickwalls and brick columns of any thickness and dimensions with first class bricks in cement mortar in foundation upto plinth.

8.2 MATERIALS

Bricks for use shall be regular in size and shape and shall conform to BDS 208: 1980 common building clay bricks (First Revision)

Cement shall be ordinary Portland Cement Type 1 conforming to BDS 232: 1974, specification for Portland Cement (Ordinary and Rapid Hardening) (First Revision)

Sand shall be as specified in Material Section. Water shall be clean and free from salt and other harmful chemicals. For saline zone special care shall be taken so that water containing salt is not used.

8.3 METHOD OF CONSTRUCTION

Cement mortar shall consist of a mixture by volume of one part cement to six parts of sand unless otherwise specified Thickness of mortar joints between bricks both horizontally and vertically shall not be more than 10 mm ($\frac{3}{8}$ ").

The size of the first class bricks shall be 9.5"x4.5"x2.75" and shall conform to the specifications of a 1st class brick as described in Section 1.2 material section.

The fineness modulus of sand used for cement mortar shall be minimum 1.2. Sand shall be screened and washed before use.

The work shall be true to plumb, curved or slopped as may be required or shown in the architectural drawings. Bricks shall be perfectly clean and free from moss or dirt of any kind. If necessary, the bricks shall be cleaned by scrubbing with steel brush and washed.

The bricks must not be used until they have been thoroughly soaked in a soaking vat for at least 24 hours in clear water. Water of soaking vat shall be replaced at regular intervals to avoid concentration of salt and dirt. Soaking of bricks to saturation frees them to great extent from salt, which otherwise would cause the plaster, white wash, colour wash, distemper or plastic paint to disintegrate and fall off in scales.

The cement and sand shall be mixed dry in the specified proportion on a clean board or platform, until the colour of the mixture is uniform. Water shall then be added sparingly, only the minimum

necessary being used to produce a workable mixture of normal consistency. The water cement ratio in no case shall exceed 0.5 by weight.

Each course of brick shall be laid level and perfect in bond with the frog mark on top so that every brick is well bedded and flushed with mortar and that the surface of the brick course is made straight and to the plumb. The vertical joints to the brick work shall be broken. The joints must be filled thoroughly with mortar leaving no gap, unless otherwise specified. The bond shall be English and no half bricks or part bricks shall be used than minimum required to complete the bond. Pouring of water in the joints at the time of laying the bricks shall be strictly prohibited. The masons must be equipped with adequate numbers of plumb bobs, levels, square and other necessary tools. No mortar joint shall exceed $\frac{3}{8}$ " (10 mm) in thickness. Wider joints seriously weaken the structure. The consistency of mortar should be attained by the minimum quantity of water in it.

Mixing of mortar in huge quantity shall be avoided. Cement mortar shall be mixed in such quantities as can be used within 30 minutes. Mortar which has crossed the initial setting time, shall not be used nor shall it be remixed with fresh mortar. Such mortars shall be discarded and removed from working site.

The top of every days work shall be covered with water proof covering to prevent rain water spoiling the days work.

The joints of brick work that shall remain below ground shall be made flush with trowels at the time of brick work and the portion of plinth above ground level should have the joints raked well to a depth of 12 mm ($\frac{1}{2}$ ") with a bent iron rod.

All fixture in the brickwork so long as they are included within the estimate for the work and shown on the plans or anticipated must be built in positions shown or as may be specified by the Engineer-in-charge, as the brickwork proceeds.

At the end of day's work, the vertical and horizontal joints must be raked to a depth of $\frac{1}{2}$ " (12mm) with a bent iron rod, so as to ensure a good adhesion to the plaster to be done subsequently.

At frequent intervals the wall surface shall be checked with the straight edge (patta) and the plumb bob to see that the wall is in correct vertical plane and that there is no depression on the surface anywhere. The straight edge should be put on various angles to ensure correct surface of brick work.

All masonry shall be built true to the plumb within the tolerances prescribed below:

- a) Deviation from vertical within a story shall not exceed 6mm per 3 m height.
- b) Deviation in verticality in total height of any wall of a building more than one story in height shall not exceed 12mm.
- c) Deviation from position shown on plan of any brickwork shall not exceed 12mm.
- d) Relative displacement between load bearing walls in adjacent stories intended to be in vertical alignment shall not exceed 6mm.
- e) Deviation of bed joint from horizontal in a length of 12m shall not exceed 6mm subject to a maximum of 12mm.

Any pipe or conduit may pass vertically or horizontally through any masonry by means of a sleeve at least large enough to pass any hub or coupling on the pipe line. Such sleeves shall not be placed closer than three diameters centre to centre nor shall they unduly impair the strength of construction.

Chases, Recesses and Holes shall be permitted within the tolerances prescribed below :

- a) Vertical chases are preferred instead of horizontal chases and chases, recesses and holes are to be considered in the structural design.
- b) Depth of vertical and horizontal chases in load bearing walls shall not exceed one-third and one-sixth of the wall thickness respectively.
- c) Vertical chases shall not be closer than 2m in any stretch of wall and shall not be located with 350mm of an opening or within 230mm of a cross wall that serves as a stiffening wall for stability.
- d) Horizontal chases shall be located in the upper or lower middle third height of wall at a distance not less than 600mm from lateral support.
- e) Recesses and holes in masonry walls shall be kept at the time of construction so as to avoid subsequent cutting. If cutting is necessary, it shall be done using sharp tools, without causing heavy impact and damage to the surrounding area.
- f) No chase, recess or hole shall be provided in half brick load bearing walls, excepting the minimum number of holes needed for scaffolding.

Walls are always to be carried out at regular height along the entire length and throughout the building. When brickwork in any section of a building can not be carried up in level courses, the work is to be racked back in regular steps of one course each. The maximum height that will be permitted to be done in one day should not exceed 1 metre in 10" walls.

Curing shall be done for at least 7 days. Proper care must be taken to see that the brickwork is kept constantly wet for 7 days. A brass hand sprayer should be used for the purpose. Should the construction agency fails to water the work to the satisfaction of Engineer-in-charge the latter shall do it departmentally and charge the cost to the contractor.

Measurement for brickwork shall be given as 250 mm width for one brick length and 375mm for one brick and a half brick length. No deduction shall be made for flues, storm drainage, sewerage, electrical conduits and other utility pipe holes, for payment of works.

Necessary scaffolding shall be done at the expenses of the contractor for proper execution of the brickwork. The rate shall include the cost of erection and removal of scaffolding, trowel finishing the brick joints during work and curing for 7 days complete.

8.4 BRICKWORK UPTO PLINTH LEVEL IN VERANDAH

The height of the plinth wall at the outside of the verandah shall be kept less than the height of the inner wall by the thickness of one brick, so that a proper outward slope can be maintained in the verandah at the time of laying of verandah floor.

8.5 PRECAUTIONS

Soaking of brick for 24 hours before use must be ensured. Mixing of mortar to correct proportion and adding correct quantity of water for correct consistency of mortar shall be carefully looked into.

Mixing of mortar in huge quantity shall be avoided. Only the quantity that can be used in half an hour shall be mixed. Before water is added sand and cement shall be thoroughly mixed in dry condition.

Masons shall not be allowed to pour water in mortar on the joints in bricks at the time of laying. The joints shall always be filled completely with trowels.

Special care shall be taken to see that brickwork is cured for at least 7 days.

BACK FILLING IN FOUNDATION TRENCHES AND PLINTH

9.1 SCOPE

The work covered by this item consists of filling the foundation trenches, plinth and interior of the sub-structure walls upto plinth level with excavated earth available or from other areas of the site or from a distant place, as instructed by the Engineer-in-charge. Sand may be used as fill materials, if specifically ordered by the Superintending Engineer.

9.2 METHOD OF CONSTRUCTION

As soon as a building is finished upto ground level, the space between the structure and the sides of the trenches shall be cleared of whatever debris might have fallen into it. After removal of debris and other foreign materials, filling shall be done in layers, not more than 15cm thick. Each layer shall be compacted at optimum moisture content before the next layer is placed on it. The density obtained shall be 95% of the maximum that can be obtained with the filled materials at optimum moisture content. Compaction shall be done by vibrator or frog hammer or vibrocompactor.

It is the common experience that cracks in the floors occur vertically on the trench line. This is due to settlement of the fill in the trench. As the width of the trench to be filled up is narrow, it is liable to be inadequately compacted. Care shall therefore, be taken to achieve the required degree of compaction of the fill materials in the trenches and in the floor areas.

Optimum moisture content of soil should be determined by testing the soil in the laboratory. When this is not possible, an approximate method of determining the moisture content which is most suitable for compaction of a given mass of soil, is to mix a few batches of the dry soil with gradually increasing water and then taking a lump of each one after the other in the palm and pressing the by the fingers. The moisture content at which the lump just retains its shape after being pressed and released, approximately be taken as optimum moisture suitable for the maximum compaction of the soil.

As soon as the wall reaches upto plinth, the filling of the interior of the walls upto the plinth should be taken. Procedure for filling and compaction shall be same as stated earlier.

The trench and plinth filling is one of the most important item in the building construction. A lot of failures in the floor caused by settlement of earth has happened. People not conversant with the technical aspect may justifiably conclude that the building having a defective floor may face

greater dangers. The floor is conspicuously exhibited and one gets a very poor impression about the workmanship, the supervision and the quality of the whole work. Utmost care must, therefore, be taken to compact the fill materials underlying the floors.

Saturating the filled materials with water shall be avoided as the water confined in the sides of the soil shall evaporate and form voids inside, resulting in harmful settlement.

The plinth fill shall be inspected by Executive Engineer/Sub-Divisional Engineer according to importance of the building before the floor is laid.

9.3 PRECAUTIONS

- a) The top minimum 6" (15cm) thick layer of fill shall invariably be of sand.
- b) Special care shall be taken that column or any other member of building is not hit or damaged during compaction.
- c) Special care shall be taken to compact the inner sides of the wall, wherein most of the cases of cracks in floors occur.
- d) Fill materials shall not be over saturated with water with the wrong impression of better compaction. Adequate compaction will not be attained if the soil is dry or very wet. Optimum moisture content is needed for proper compaction of soil.
- e) No loose brick or brick bat shall be allowed to get buried inside the fill materials. Any other loose materials such as pieces of bamboo, wood, paper, vegetable matters shall also be removed before the earth filling is started.
- f) Big lump of earth or the like shall be broken to small pieces for proper compaction.
- g) Fineness Modulus of sand used for filling trenches and floors shall be minimum 0.8 and it should be pure sand with minimum quantity of silt or clay.
- h) Before sand filling, sample shall be submitted to Engineer-in-charge for approval.
- i) Where it is not possible to use vibrator or frog hammer, the compaction shall be done with the help of a steel hammer of minimum 10 lbs weight.

DAMP PROOF COURSE**10.1 DEFINITION**

A damp proof course is a continuous layer of damp resisting material provided with the objective of protecting the superstructure of a building against dampness.

10.2 CAUSES AND SOURCES OF DAMPNES

Absorption of moisture by the materials is one of the main causes of dampness. Due to granular nature of materials, moisture finds an easy access through the voids and this aided by the capillary action assists the moisture to travel in different directions. Thus due to either bad workmanship or use of defective materials, moisture may find its way to the interior through the wall, floor or roof.

The major sources of dampness are :

- a) Dampness rising through the foundation walling. Moisture from wet ground may rise well above ground level on account of capillary action.
- b) Splashing rain water which rebounds after hitting the wall surface may also cause dampness.
- c) Rain water may percolate through roof covering. Faulty eave course and eave gutters may also allow the rain water to descend through the top of the outer wall.

10.3 EFFECTS OF DAMPNES

The various effects caused by the dampness of the building may be summarised as below :

- a) It causes efflorescence which may ultimately result in the disintegration of bricks, tiles etc.
- b) It may result in softening and crumbling of plaster.
- c) It may cause bleaching and flocking of paint with the formation of coloured patches.
- d) It may result in the warping, buckling and rotting of timber.
- e) It may lead to the corrosion of metal.
- f) It may deteriorate the electrical fittings.
- g) It promotes growth of termites.

10.4 MATERIALS

Coarse aggregate shall consist of picked jhama chips graded from 12mm to 6mm. Fine aggregate shall be 50% local sand of F.M. 1.2 and 50% Sylhet sand of F.M. 2.5 minimum. Cement shall be ordinary Portland cement type-1. Water shall be clean and free from chemicals and salt.

10.5 METHOD OF CONSTRUCTION

The surface over which the damp proof course is to be laid shall be thoroughly scrapped to remove mud, dirt etc. and washed clean with clean water.

The mix proportion shall be 1:1½:3 and thickness 75mm (3").

Shuttering shall be done on both sides of the wall. The shuttering shall be strong and so fixed that it does not get disturbed during compaction and the concrete slurry does not leak out.

The concrete prepared by mixing the ingredients shall be laid and tampered roughly to make a dense mass.

After 24 hours of its laying, the concrete layer shall be cured for at least 7 days. After curing is complete the surface shall be left to dry out to receive a coat of hot bitumen. The dried surface of concrete shall be properly cleaned with brush and finally with a piece of cloth soaked in Kerosene oil.

A coat of Bitumen 80-100 penetration, heated to 300°F shall be applied uniformly on the hardened and dry concrete surface using 30 lbs per 100 sft per coat. Bitumen shall be applied with brush.

10.6 PRECAUTIONS

The top surface of the D.P.C. shall be in the same level of floor finish and shall not be carried across doorways or other openings. The upper layer of cement concrete floors shall be continued over such openings and shall be laid at the same time as floor.

A damp proof course shall not be less than 15cm (6") above the highest level of the ground and shall be above the normal level to which water splashes from the ground when it is raining.

The damp proof course should be continued unbroken throughout the length and thickness of wall.

The base of D.P.C. layer shall be even. The uneven base shall cause the retention of air voids between the base and the D.P.C., which is not desirable.

If there is a cavity wall D.P.C. shall be laid separately for the two leaves.

BRICK WORK IN SUPERSTRUCTURE

11.1 SCOPE

The work covered by this item consists of constructing brick wall and brick columns of 250 mm thickness or more with 1st class bricks in cements mortar (1:6)/(1:4) or any other proportion as stated in the bill of quantities in the superstructure.

11.2 METHOD OF CONSTRUCTION

This should generally be made as specified for the brickwork in foundation upto plinth level. However, it is to be remembered that utmost care is needed in the superstructure wall as it will remain exposed and the workmanship of the plumb, the uniformity of the surface etc. will tell very seriously on the finishing and look of the building.

11.3 REINFORCED BRICK WALL

Brickwalls may be reinforced with M.S. bars for safety against earthquake or high wind. Reinforced brickwalls shall be designed properly as per code by the design office before execution at the site. Care should be taken so that reinforcements are well covered with mortar and their ends are anchored to the walls connecting the R.B. walls at right angles to it.

11.4 BRICK ARCHES

11.4.1 Types of arches

Depending upon the nature of work and quality of bricks used brick arches may be classified as Rough arches, axed brick arches, gauzed brick arches etc.

Rough arches are built with ordinary bricks which are not cut to wedge shapes. In order that all the bed joints may be normal to the curve of the arch, the joints are made wedge shaped. Thus the joints at the extrados are wider than those at the intrados. The wedge shaped joints spoils the appearance of the arch, as such rough arches are seldom used for facing brickworks. It is suitable for plastered surface.

In axed brick arches, the bricks are cut to wedge shape. Thus the joints of arches are of uniform thickness. Since the wedged shaped units can not be finely dressed, the appearance of the arch is not very attractive.

For gauzed brick arches, bricks are accurately prepared to a wedge shape for the arch construction. This is difficult method and special type of bricks are used in this type of arch construction.

Arches are also defined in names derived from the shape of the curve like flat arch, semi-circular arch, segmental arch etc.

When used over opening of doors or windows, the flat arch acts similar to a lintel. Flat arches also known as straight arch is laid with its bed joints either vertical or radiating to a centre. Flat arches are not strong compared with other forms.

The semi circular arch derives its name from the shape of the curve given to the arch soffit. Semi circular arches are the strongest and exert no thrust on abutments or piers.

Segmental arches are segmental in shape and is commonly provided for openings of various sizes. The bed joints of segmental arches radiate from a common point which lies below the springing line and is equidistant from all points on the arch curve. When used over a lintel segmental arch is termed as 'relieving arch'. A good rule for the radius of segmental brick arches over doors and windows or other small openings is to make the radius equal to the width of the opening.

11.4.2 Method of construction

The usual centering for arch construction consists of a horizontal frame known as centre or turning piece. The centering differs according to the shape of the arch curve and the span of the opening. The centering may be of timber or brickwork. The upper surface of the centering is given the shape of the soffit of the arch to be constructed.

After the centering is properly erected in position, skewbacks are first prepared and voussoirs are arranged in the form of arch curves starting from the skewbacks and proceeding towards crown. Keystone is finally inserted to lock all the voussoirs in position. The voussoirs must be properly bedded to ensure strength and stability of the arch.

The thickness of arch ring may be taken for brickwork in cement mortar 1:4 as follows :

- | | |
|---------------------|-----|
| a) Upto 5'-0" | 10" |
| b) 6'-0" to 14'-0" | 15" |
| c) 15'-0" to 25'-0" | 20" |

The thickness of arch ring at springing may be taken the same as at crown for small spans. In case of large spans over 6m, the thickness at the springing should be increased by about 20 percent.

It is preferable to provide all arches of span 6'-0" and above with keys. For spans 6'-0" to 12'-0", there should be one key at the crown and for spans above 12'-0", additional keys should be provided so that the distance between the keys is not more than 9'-0" measured along the intrados.

Keys should extend over the full thickness of the arch.

11.5 PRECAUTIONS : Precautions shall be same as those stated in section 8.5

**BRICK WORK WITH SPECIAL QUALITY
SORTED OUT BRICKS****12.1 SCOPE**

The work covered by this item consists of constructing brickwall and brick pillar of 250mm thickness or more with special quality sorted out 1st class bricks in cement mortar (1:4) and flush pointing the exterior surface with cement mortar 1:2.

12.2 MATERIALS

Bricks for use shall be regular in size and shape and shall conform to BDS 208: 1980 common building clay bricks (First edition). Special quality sorted out first class bricks having good texture, exact size, shape, edge and corners shall be used. There shall not be any crack or blemishes in the bricks.

Cement shall be ordinary Portland Cement Type-1 conforming to BDS 232: 1974.

Sand shall be as specified in Material Section.

Water shall be clean and free from salt and other harmful materials. For saline zone special care shall be taken so that water containing salt is not used.

12.3 METHOD OF CONSTRUCTION

Before starting the work, sorted out bricks of special quality shall be stacked separately for approval by the Engineer-in-charge. No brick shall be used from the ordinary stack of 1st class brick unless it is sorted separately for this particular type of brick work.

The work shall be carried out as per specification laid down in section 11.2 excepting that cement mortar shall consist of one part of cement to four parts of sand by volume.

Care shall be taken that exposed bricks are not stained as the work proceeds. No rubbing of faces shall be allowed to remove smear or stain. While putting mortar between joints special care shall be taken so that mortar does not roll down the face of the brick.

As work progresses clamps, anchors, hold-fasts and other items of various trades shall be fixed simultaneously. No cutting or patching of the completed masonry work shall be permitted after the completion of the brick work. Holdfasts and similar fixtures shall be built in the surrounding brickwork in 1:3 cement mortar without disturbing the joint pattern.

Brick joints shall be water tight and no leakage shall be allowed.

Brick joints shall be of uniform thickness and not more than 10mm (3/8"). Both vertical and horizontal joints shall be checked from time to time so that uniformity of thickness is maintained throughout the brickwork.

During brick laying, the joints on the exposed surface shall be carefully raked to a depth of 10mm (3/8"). Pointing shall follow after the masonry has been cured for 7 days. Masonry surfaces and joints shall first be thoroughly scrubbed and cleaned with clear water. When the wall surface is dry, pointing mortar with a cement sand ratio of 1:2 shall be applied with small steel trowels to fill the joints. Extreme care shall be taken that the mortar does not spread over the edges of the brick. The mortar shall be compacted by pressing the trowel hard against the joint and finished by drawing the trowel with a steady, firm tangential motion over the surface. The mortar consistency shall neither be too stiff nor too soft but must be of a consistency to take a polish at the time of finishing. The surface of the finished mortar shall be flush with the brick surface.

Flush pointing shall be cured for 7 days.

12.4 PRECAUTIONS

Only selected brick of uniform size and texture shall be used.

Selected bricks shall be stacked separately for this particular work.

Blemishes and spreading of mortar on the brick surface shall be strictly controlled.

As the brick surface shall remain exposed special care shall be taken to give the surface a decent look and uniform joints and texture.

As there will be no plaster over the surface, special care shall be taken to fill the joints, both vertical and horizontal, properly to avoid leakage of water through the joints.

**BRICK WORK WITH 10 HOLES
MACHINE MADE BRICKS****13.1 SCOPE**

The work covered by this item consists of constructing brick walls and brick pillars of 250mm thick or more with machine made 10 hole ceramic bricks with cement mortar.

13.2 MATERIALS

Bricks shall be of size $9\frac{1}{2} \times 4\frac{1}{4} \times 2\frac{3}{4}$ made by machine having uniform texture, good finish, well defined corners and edges and surface made for durable and heavy duty performance. It should be dense having low water absorption and low porosity.

Specification for cement and sand shall be same as described in Section 12.2. Cement mortar shall consist of a mixer by volume of one part of cement to four parts of sand.

13.3 METHOD OF CONSTRUCTION

The work shall be carried out as per specification given in section 11.2 excepting that the mix proportion shall be 1:4 and machine made ceramic bricks shall be used in place of ordinary bricks. Special care shall be taken as described under section 12.3.

13.4 PRECAUTIONS

There is widespread complain about leakage of machine made brick wall and dampness on the inside face of the wall. Special care should be taken so that mortar joints are made full and solid and after completion of the brickwork pointing work done properly to avoid leakage.

Careful laying of brick, prevention of excessive mortar, spilling and staining of brickwork are very important in achieving brickwork of good appearance, low maintenance and prevention of efflorescence.

Mortar must be mixed with fresh clean water and sand free from salt.

FACING BRICK WORK**14.1 SCOPE**

The work covered by this item consists of constructing facing brickwork or cladding brickwork in superstructure with 200x100x50mm machine made ceramic hard pressed bricks with cement mortar (1:4).

14.2 MATERIALS

Facing bricks shall be of size 200x100x50mm hard pressed and machine made. Colour shall be uniform, corners sharp without any crack, size shall be uniform. Cement and sand shall be same as these stated under section 13.2.

14.3 METHOD OF CONSTRUCTION

Before laying the facing brick over ordinary brick work, a true to plumb surface both vertically and horizontally shall be prepared on brick surface with sand cement mortar few days before actually laying the facing bricks. The surface shall be used and roughened to receive the facing brick. This is required to have a perfectly level bed for the facing brick work.

Exposed bricks shall be laid in courses accurately spaced by means of a wooden template of 40x100x750mm ($1\frac{1}{2}$ "x4"x30") long having a longitudinal tongue of 6x6mm ($\frac{1}{4}$ "x $\frac{1}{4}$ "). The tongue shall be perfectly straight and true. The thickness of bed joints shall be 6mm ($\frac{1}{4}$ "). The thickness of vertical joints shall be as small as possible but not exceeding 6mm ($\frac{1}{4}$ "). A recess of 6mm ($\frac{1}{4}$ ") in joints on the pointed face shall be carefully preserved. The work shall be cured for 7 days.

14.4 PRECAUTIONS

Brick used for facing brickwork for a particular building should have uniform colour to give the building a uniform look.

Specially trained masons experienced in facing brickwork shall be engaged for this work.

Special care shall be taken so that mortar does not flow and stains the surface of the facing bricks.

Consistency of the cement mortar should not be too loose to flow on the face of the brick work.

Both horizontal and vertical joints should be of uniform depth and thickness to give the surface a descent look.

FACING BRICK WORK IN FLOOR/PAVEMENT**15.1 SCOPE**

The work covered by this item consists of providing facing brick work in floor/pavement with machine made facing bricks. It may be either 100mm thick brick-on-edge or 50mm thick flat.

15.2 MATERIALS

Bricks shall be machine made pressed bricks of size 200x100x50mm (8"x4"x2").
Specification for cement and sand shall be as stated under section 12.2.

15.3 METHOD OF CONSTRUCTION

The cement mortar for preparation of bed and making joints between bricks shall consist of a mixer by volume of one part of cement to four parts of sands. The thickness of joints between bricks shall not be more than 6mm ($\frac{1}{4}$).

Before commencement of work, the bed shall be made perfectly level or set to any other suitable grade. No wearing course is proposed on this type of work.

After preparation of the bed, ceramic bricks shall either be laid flat or on edge on a bed of mortar keeping a gap of 6mm. The joints between the bricks shall then be solidly filled to the full depth by sand-cement mortar. Flush pointing shall be done as per specification stated under section 12.3. The work shall be cured for 7 days.

After completion of work, the top surface, shall be carefully cleaned of any spare or loose mortar or any other stain.

The same work can be done also by 17 hole/10 hole ceramic brick or ordinary 1st class bricks on edge.

15.4 PRECAUTIONS

Level or grade should be properly maintained for drainage of rain water.

Vertical joints should be properly filled with mortar so that water does not leak into the bed and damage the work.

Green works should be fenced properly so that humans and cattles do not tread on it and damage the work.

No mud band should be used for curing the work to avoid stain on the brick.

REINFORCED CONCRETE WORK

16.1 SCOPE

The work covered by this item consists of but not limited to reinforced concrete construction in foundation footings, columns, lintels, beams, slabs, wall panels, retaining walls, water tanks, reservoirs etc. The R.C.C. members may be cast in situ or precast in the work site or in a central manufacturing workshop from where they are carried and fixed in the desired position in the proposed structure.

16.2 CEMENT

Cement shall be ordinary Portland cement Type 1 conforming to BDS 232 - 1974 or any other type as specified in the design.

Requirements of cement shall conform to specifications as stated in section 5.2.1a of Bangladesh National Building Code (BNBC) in addition to the requirement of BDS 232 - 1974.

No cement which has been stored through a monsoon or for a period more than six months shall be used for reinforced concrete until samples have been tested and found to meet the requirement of standard specification. Approval of the Engineer-in-charge shall be taken before any cement is used.

Cement bags containing clods giving indications of starting of initial setting shall not be used in R.C.C. work. It is important that the strength of cement is ascertained by testing before use. Cement shall never be measured loose but shall be so done in terms of bags, care being taken to determine the volume content of cement in bags.

The cement shall be stored at site in such a manner as to permit easy access for proper inspection, handling and identification of each shipment and in a suitable weather tight building that will protect the cement from dampness and wastage.

Cement shall be protected from moisture and damage in transit and shall be stored in the site in a store provided with a wooden floor raised not less than 30 mm from the ground. Cement shall not be stacked higher than 6 bags.

Cement bags shall not be piled against the wall, a space of 300 mm shall be left between the exterior walls and the cement bags. The bags shall be placed close together in the pile to reduce circulation of air as much as possible. For extra safety, particularly during monsoon, the pile of cement bags shall be enclosed completely by polythene sheet or covered with a tarpaulin.

Batches of cement shall be used for the work in the order in which they are delivered to the site. Each consignment shall be stacked separately, so that the older cement may be identified readily for use earlier.

Only one brand of cement shall be used for a particular casting work except by written permission from the Engineer. Different types of cement shall be stored separately and shall not be mixed.

Use of rebagged cement shall not be allowed.

Engineer, at his discretion shall test cement which he feels to have deteriorated through age, damage to bags, improper storage or for any other reason. In the event of any sample being found to be not in accordance with BDS 232-1974 or any other standard as specified, the whole consignment from which the sample comes shall be rejected and removed from the site immediately notwithstanding any previous acceptance other-wise.

16.3 AGGREGATE

Concrete aggregate shall conform to the "Coarse aggregate and fine aggregate from Natural source for concrete (BDS 243-1963) and made from Grade 'A' brick conforming to BDS 208-"Specification for common building clay bricks".

16.3.1 Coarse Aggregate

Coarse aggregate shall consist of either crushed stone or picked jhama brick chips as specified.

All coarse aggregate shall be cleaned and made free from dust and other impurities by screening and washing in clean water immediately before use. Aggregate coated with clay, salt, organic matter or crushed dust will not bond with surrounding cement paste.

Maximum nominal size of coarse aggregate shall not be larger than the most restricting of the following:

- a) $1/5$ th the narrowest dimension between sides of form.
- b) $1/3$ rd the depth of the slabs.
- c) $3/4$ th minimum clear spacing between individual reinforcing bars, or bundle of bars or prestressing tendons or ducts.

The above limitations may be relaxed if, in the judgement of the Engineer, workability and methods of construction are such that concrete can be placed without honey comb or voids. Minimum size of coarse aggregate shall be such that it will be retained 100% by sieve No.4.

It is of major importance that aggregate be non-reactive with cement and water and that it be structurally sound, strong and durable.

The contamination of aggregate with top soil, humus or earthy materials containing products of organic decay even in small amounts is practically certain to cause early disintegration of the member.

One other important characteristic of coarse aggregate is surface texture. A material of rugged surface is by reason of its greater likelihood of mechanically adhering to cement paste more desirable than another of vitreous, or smoothly structured surface.

Size and shape as well as the relative number of particles of different size, are important in determining the suitability of materials for use as coarse aggregate. Since major function of aggregate is to act as bulk filler, the particle offering least resistance to rearrangement among their kind are most desirable. In other words, the aggregate should be well graded.

The angular shapes of the coarse aggregate play a very important role in attaining the compactness and strength of the concrete.

River shingle with its round surface give almost the same compressive strength as the sharp faced brick chips. As such to attain greater strength of concrete boulders should be brought to site and broken to proper size to use as coarse aggregate.

16.3.2 Fine Aggregate

For concrete, any sound filler materials that will pass through a sieve having square openings of $1/4$ inch size shall be reckoned as sand or fine aggregate. It should be well graded particles and

retained on No.100 sieve in which not more than 5% dust is allowed. Coarseness of sand plays a very important role in the compactness and strength of concrete. Every endeavour should be made to obtain the coarsest variety of sand and the minimum fineness modulus (F.M) of sand for concrete work shall be 2.5. Particle larger than $\frac{1}{4}$ inch in size are declared as coarse aggregate.

It should be free from clay and other foreign materials as far as possible. The amount of clay contained in sand may be ascertained by stirring samples of sand in clear water in glasses and allowed to settle for about 15 minutes after brisk stirring. The thickness of clay deposit will be apparent and any staff containing appreciable amount of clay shall be rejected.

Sand shall be well graded and must contain all sizes from the maximum specified down to the smallest size.

Sand should be washed thoroughly to get rid of the clay and other undesirable materials particularly salt before use in R.C.C.

16.4 WATER

Water used in mixing concrete shall be clean and free from injurious amount of oils, acids, alkalis, salts, organic materials and other substances that may be harmful to concrete or reinforcement.

Nonpotable water shall not be used in concrete only if specified mortar test cubes made with non-potable water produce at least 90% of the strength achieved with potable water.

Under no circumstances, saline water shall be used for concrete.

16.5 STEEL REINFORCEMENT

Reinforcing steel shall conform to "Specification for Steel Bars and Wires for the Reinforcement of concrete" (BDS 1313).

Reinforcing steel shall be deformed bars of Grade 40 and Grade 60 having f_y equals to 275 MPa and 400 MPa respectively. Bars manufactured only from billet steel shall be used as reinforcing bars. Bars produced from scrap shall not be used as reinforcing bars under any circumstances.

Before use reinforcing bars shall be tested either from BUET or any other standard laboratory approved by the concerned Executive Engineer(Design), to ascertain its yield stress, ultimate strength, chemical composition, percentage elongation etc. The result shall have to conform with the design strength specified by the Design Engineer.

Allowable tensile values of reinforcing bars shall be :

- a) $f_s = 125$ MPa (18000 Psi.) with mild steel (Billet) deformed bars Grade 40 having minimum $f_y = 276$ MPa (40,000 Psi).
- b) $f_s = 165$ MPa (24000 Psi) with deformed bars Grade 60 having minimum $f_y = 415$ MPa (60000 Psi).

16.6 CONCRETE STRENGTH

Standard cylinder crushing strength of concrete at 28 days shall be minimum :

- a) 17 MPa (2500 Psi) with brick jhama chips and mix proportion (1:2:4)
- b) 20 MPa (3000 Psi) with brick jhama chips and mix proportion $1:1\frac{1}{2}:3$
- c) 25 MPa (3500 Psi) with crushed stone coarse aggregate and mix proportion: $1:1\frac{1}{2}:3$

7 days crushing strength shall not be less than 70% of the specified 28 days crushing strength.

Testing of concrete shall be done frequently and test result furnished to the design office for checking and record.

Slump test shall be performed at site for every days concrete mix to ascertain the consistency and water cement ratio of the mix.

16.7 GENERAL DESIGN REQUIREMENTS

1. Structural drawings shall be read in conjunction with Architectural drawings. For any contradiction between structural and architectural drawings, structural designer shall be consulted for any correction or modification.
2. All written dimensions shall be followed and not scaled from drawing. For dimensions of structural members like slab, beam, column etc. structural drawing shall be followed.
3. No deviation from structural design is advised without the approval of the concerned designer.
4. Cement, aggregate, M.S. Rod shall be tested either in BUET or in a standard testing laboratory approved by the concerned Executive Engineer(Design) and test results shall be furnished regularly to the design office for checking and record.
5. Polythene sheet as per P.W.D. schedule of rates shall be laid underneath all concrete work to prevent leakage.
6. Plain and Reinforced concrete casting must not be done without the presence of an officer in the rank of Sub-Divisional Engineer. Shuttering, propping and levelling work of R.C.C. shall be checked and certified by the Executive Engineer in the site order book.
7. Cement blocks of required thickness made of (1:2) cement mortar shall be used under or sides of the reinforcing bars to maintain clear cover. Under no circumstances, broken bricks shall be used as clear cover blocks.
8. Conduits and pipes embedded in concrete shall satisfy the following requirements :
 - a) Concealed PVC or any other pipe laid in the slab for electrical or any other trade shall be placed at the middle between top and bottom reinforcement. Under no circumstances, it shall be laid beneath the bottom reinforcement.
 - b) Conduits and pipes with their fittings, embedded within a column shall not displace more than 4% of the area of cross section of column.
 - c) Conduits and pipes shall not be larger in outside dimension than 1/3rd the overall thickness of slab, beam or wall in which they are embedded.
 - d) Conduits and pipes shall not be placed closer than three times the diameter or width on centres.
 - e) Concrete cover for pipes, conduits or fittings shall not be less than 0.75" (20 mm) for concrete not exposed to weather or in contact with ground nor 1.5" (40mm) for concrete exposed to earth or weather.
9. The following minimum concrete cover shall be provided for reinforcing bars for cast-in-place reinforced concrete :

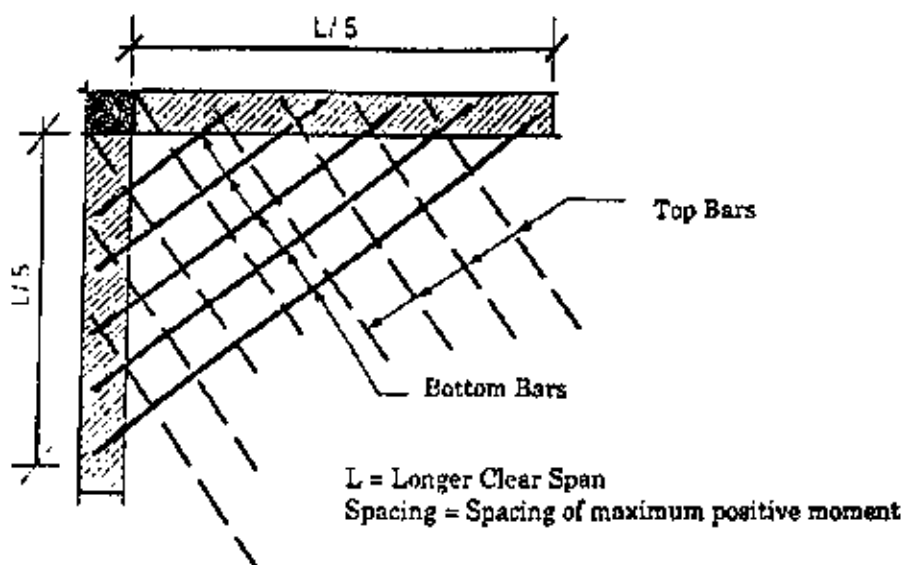
Non-Saline Zone

• Slabs, walls	3/4" (20mm)
• Beams, girders,	
Columns (to ties, stirrups or spirals)	1 1/2" (40mm)
Concrete in contact with soil.	3" (75mm)

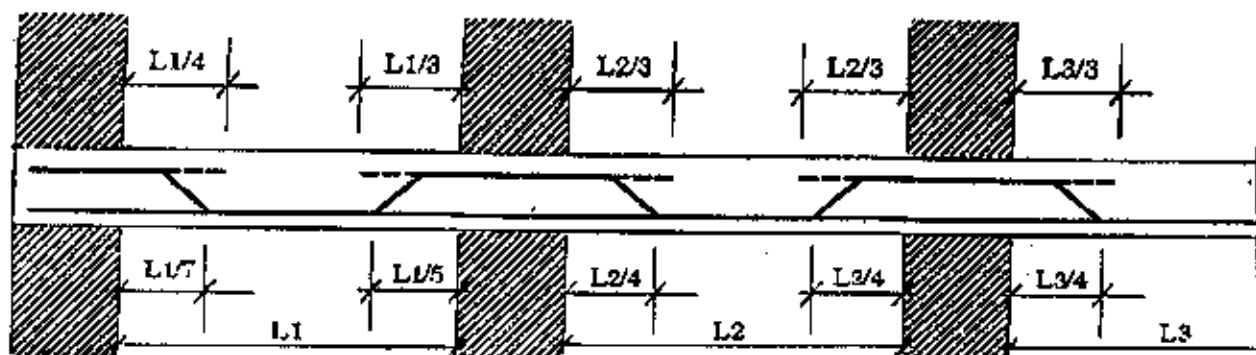
10. Beams, girders or slabs supported on R.C.C. columns or walls shall not be cast or erected until concrete in the vertical support member is no longer plastic.
11. Clear distance between parallel bars (except in columns and between multiple layers of bars in beams) shall not be less than the nominal bars diameter, 1 1/3rd times the size of coarse aggregate nor 1 inch (25mm).
12. Where reinforcing bars in beams and girders are placed in two or more layers, the clear distance between layers shall not be less than 1" inch and the bars in upper layers shall be placed directly above those in the lower layers.

13. In column, the clear distance between longitudinal bars shall not be less than $1\frac{1}{2}$ times the bar diameter, $1\frac{1}{2}$ times the maximum size of coarse aggregate nor $1\frac{1}{2}$ inch (40mm).
14. Corner reinforcement shall be provided in any exterior corner of two way slab system. Spacing of reinforcement shall be equal to the spacing of maximum positive reinforcement.

Corner Reinforcement for two-way slab



15. Continuous slabs with nearly equal spans, larger of the two adjacent spans not to exceed the shorter by more than 20%, uniformly loaded in which not more than about one half the tensile reinforcement is to be bent, the position of Bend-ups and extra bars shown thus.



16. Minimum lap lengths for deformed bars in tension with $f_y = 415 \text{ MPa}$ and $f_c = 25 \text{ MPa}$

Bar	mm	6	10	12	16	19/20	22	25	28
Dia	inch	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/4
Top Bar	mm	460	460	460	535	635	890	1145	1475
	inch	18	18	18	21	25	35	45	58
Bottom Bars	mm	305	305	305	380	460	635	815	1040
	inch	12	12	12	15	18	21	32	41

17. Minimum lap length for deformed bars in compression with $f_y=415$ MPa and $f_c=25$ MPa.

Bar	mm	6	10	12	16	19/20	22	25	28
Dia	inch	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/4
Lap	mm	305	305	380	510	610	690	765	865
Length	inch	12	12	15	20	24	27	30	34

18. Minimum lap length for deformed bars in tension with $f_y=276$ MPa and $f_c=17$ MPa

Bar	mm	6	10	12	16	19/20	22	25	28
Dia	inch	1/4	3/8	1/2	5/8	3/4	4/8	1	1 1/8
Top	mm	460	460	460	460	535	690	890	1145
Bar	inch	18	18	18	18	21	27	35	45
Bottom	mm	305	305	305	305	380	810	660	815
Bar	inch	12	12	12	15	15	20	26	32

19. Minimum lap length for deformed bars in compression with $f_y=276$ MPa and $f_c=17$ MPa

Bar	mm	6	10	12	16	19/20	22	25	28
Dia	inch	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8
Lap	mm	305	305	330	430	510	585	660	760
length	inch	12	12	13	17	20	23	26	30

20. Minimum lap length for deformed bars in tension with $f_y=276$ MPa and $f_c=25$ MPa

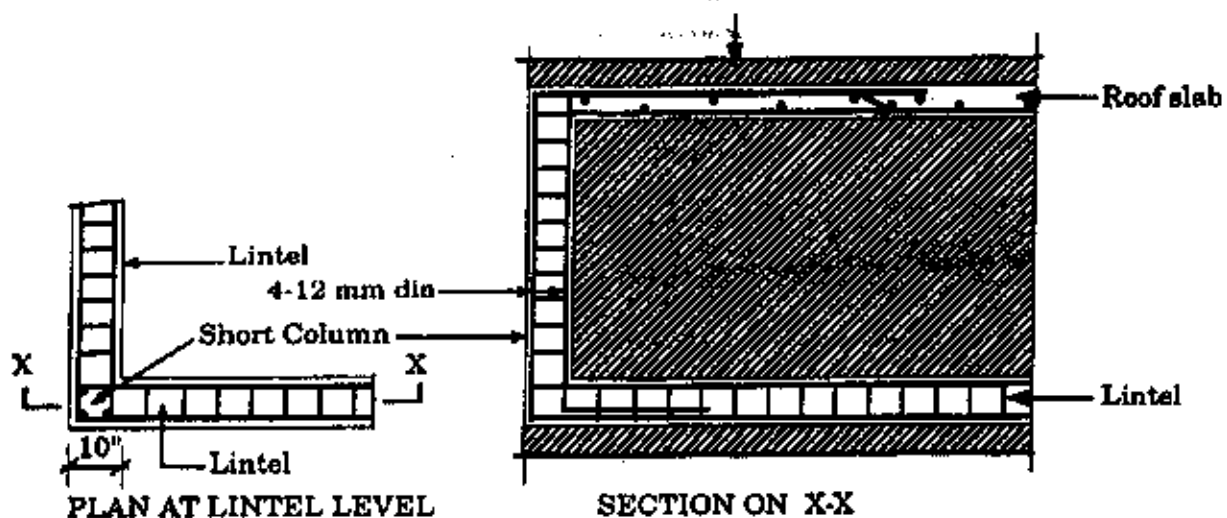
Bar	mm	6	10	12	16	19/20	22	25	28
Dia	inch	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8
Top	mm	460	460	460	460	460	610	790	970
Bar	inch	18	18	18	18	18	24	31	38
Bottom	mm	305	305	305	305	430	560	690	
Bar	inch	12	12	12	12	12	17	22	27

21. Lap length for deformed bars in compression with $f_y=276$ MPa and $f_c=25$ MPa

Bar	mm	6	10	12	16	19/20	22	35	28
Dia	inch	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8
Lap	mm	305	305	330	415	500	580	660	760
length	inch	12	12	13	16	20	23	26	30

22. The lapping in the reinforcement shall be avoided as far as possible at the point of maximum bending moment and shall be staggered at different places where it occurs.

26. Exterior corners of two-way roofs or floors with or without parapet having provision for future extension), supported freely on masonry walls, shall be anchored down to the lintel by providing short column at the corner and necessary reinforcing steel in the slab for the restraining moment thus developed to avoid horizontal crack in the masonry wall.



16.8 R.C.C. WORK IN SALINE ZONE

In the coastal area of Bangladesh and offshore Islands saline environment prevails. Due to salinity in the weather many existing buildings have shown cracks, spalling of concrete and corrosion in the reinforcing bars.

Special provisions in the design and construction of R.C.C. structures have to be made to make the buildings safe and durable which include denseness and non-porosity of concrete by using rich concrete mix and increased protection (clear cover) of reinforcing bars for areas where concrete is exposed to corrosive atmosphere and external source of chloride.

Following are some of the measures and design criteria decided by the Chief Engineer on the basis of recommendations of a high powered committee which is to be followed for Saline Zone.

1. For R.C.C. work brick aggregate shall be replaced by crushed stone aggregate where saline weather is prevalent.
2. Standard cylinder crushing strength of concrete at 28 days shall be minimum 24 MPa (3500 Psi) with crushed stone as coarse aggregate. Minimum mix ratio of Reinforced concrete shall be $1:1\frac{1}{2}:3$ by volume. 7 days crushing strength shall not be less than 70% of the specified 28 days crushing strength.
3. Fineness modulus (F.M.) of sand for R.C.C. work shall be minimum 2.5.
4. Deformed bars of Grade 40 or Grade 60 shall be used as prescribed by Superintending Engineer, Design Circle.
5. Clear cover for reinforcement shall be as follows :

a) Slabs	40mm (for buildings beyond 6 km from sea shore or river bank it may be reduced to 25mm)
b) Beams and columns (from stirrups or ties)	50 mm
d) Concrete cast against and permanently exposed to earth	75 mm
6. Sweet water shall be used for all R.C.C. work.

7. All R.C.C. work shall be mixed by mixer machine and no hand mixing shall be allowed.

The following districts and thanas have been identified as Zone of saline weather vide Chief Engineer's Memo. No.1997-D-8 dt.18.8.93 and No.1610 D-4 dt. 28.8.93.

Dist.	Thana
Cox's Bazar	Cox's Bazar Kutubdia Mohesh Khali Chokoria Ramu Teknaf Ukhia
Chittagong	Port Area Bash Khali Miresharai Shitakunda Anwara Patia Sandwip
Laksmipur	Laksmipur (Char Area) Raipur Ramgati
Feni Noakhali	Sonagazi Hatiya Companigonj Noakhali Sadar (Char Area)
Bhola Barisal	All Thanas Bakergonj (Durgapasha Union) Barisal Sadar (Chandra Mohan Union)
Barguna	Barguna Amtali Patharghata Betagi
Perojpur Khulna Bagerhat	Matbaria All Thanas Sharankhola Manglaport
Satkhira	Shyamnagar Kaligoni Ashashuni
Patuakhali	Patuakhali Dumki Galachipa Bauphal Dashmina Kalapara Mirjagonj

16.9 ADMIXTURE

An admixture is an extra component sometimes added to a concrete mixture for the purpose of creating a special property or for neutralizing a normal characteristic of the concrete, or to correct some deficiency of the mixture.

Chemical admixtures are added to concrete for the purpose of modifying the normal plastic life of the mixture or for influencing its rate of gaining hardness and strength. A disadvantage of most chemical admixtures is that small changes in their amount cause great change in their action. Furthermore, some may retard one type of cement and accelerate another.

Thus, successful use of admixtures requires, precautionary study with the associated cement before they are used, because their adequacy of performance is difficult to measure at a construction site during the progress of work as consistency of action is not visually evident, abnormality of behaviour is not immediately disclosed and may not become known until some years after the structure is built.

There are several dispassionate reasons why some Engineers are skeptical of admixtures in general. Successful use of these requires watchful observation and vigorous control, other-wise if they are used beyond certain limits, they may be disastrous. Successful use can only be achieved by expert technicians.

Prior approval by the Engineer shall be required for the use of admixture in concrete.

16.10 WATER-CEMENT RATIO

For complete hydration of a given amount of cement, an amount of water equal to 25 percent of that of cement, by weight is needed chemically. An additional 10-15 percent must be present, however, to provide mobility for the water in the cement paste during the hydration process so that it can reach the cement particles. This makes for a total minimum water cement ratio of 0.35-0.4 by weight. This corresponds to 4.5 gallon of water per sack of cement, the most customary way of expressing the water cement ratio. Water cement ratio in concrete is generally considerably larger than this minimum to provide the necessary workability of the concrete mix.

Provided the mix is sufficiently workable to be adequately compacted, the concrete with least amount of water gives the maximum strength. The quantity of water to be used in the mix should be minimum, consistent with the workability of the mix. Workability indicates the condition with which concrete can be placed and compacted in the forms. It should be remembered that an excess water in a concrete mix makes the concrete weak, porous and permeable to moisture, reduces the durability of the concrete and increases the shrinkage stress in it, resulting in cracks.

Concrete consistency is frequently measured by the slump test. A metal mould in the shape of a truncated cone 12 inch high is filled with fresh concrete in a carefully specified manner. Immediately upon being filled, the mould is lifted off and the slump of the concrete is measured as the difference in height between the mould and the pile of concrete.

The slump is a good measure of total water content in the mix and should be kept as low as is compatible with workability.

The following limits of slump should be followed as a guide line :

Sl.No.	Type of work	in inch
1.	Slab, beam & column	2"-6"
2.	Foundation, footing, wall etc.	1"-5"
3.	Mass concrete	1"-3"

16.11 CONCRETE MIX PROPORTION

Proportions of materials for concrete shall be such that:

- Workability and consistency are achieved for proper placement into forms and around reinforcement, without segregation or excessive bleeding.
- Resistance to weather and other special exposure conditions to meet the durability requirements, are attained.
- The mix attains the designed strength. Concrete proportions, including water - cement ratio shall be established on the basis of field experience and/or trial mix with materials to be used.

Normally a mix proportion of 1:2:4 with brick chips as coarse aggregate shall be used for small works. In big and important structures and also in the saline zone, a richer mix proportion of 1:1½:3

with either brick chips or crushed stone as coarse aggregate shall be used depending upon the strength requirements and denseness of the concrete.

16.12 PREPARATION BEFORE MIXING OF CONCRETE

Before mixing concrete, preparation shall include the following:

- a) All equipment for mixing and transporting concrete shall be cleaned.
- b) The platform where the concrete shall be poured from mixer machine shall be cleaned with water and free from debris and other harmful materials.
- c) Containers for measuring aggregates, sand, water, cement shall be checked and approved by the Site Engineer.
- d) All debris shall be removed from spaces to be occupied by concrete.
- e) Form shall be properly cleaned and coated.
- f) Masonry filler units that will be in contact with concrete shall be soaked thoroughly.
- g) Coarse aggregate shall be thoroughly watered and cleaned of all foreign materials, silt and mud.
- h) Reinforcement shall be thoroughly cleaned of deleterious coatings.
- i) Concrete blocks for maintaining clear cover shall be properly placed.
- j) Water shall be removed from the place of deposit before concrete is placed.
- k) All laitance and other unsound materials shall be removed before additional concrete is placed against hardened concrete.
- l) All reinforcements shall be checked to verify whether the rods of the specified number, diameter, length and shape with proper laps have been provided and the necessary clearance maintained as shown in the design drawing. It shall also be checked if the rods have been tied rigidly by wires, with the correct spacing in between. The effective depth shall be checked to see whether it conforms to that shown in the drawings.
- m) No rectification works, for any part of the proposed R.C.C. work, whether it relates to bending, binding of the reinforcement or to the correction of form work shall be allowed to be left for the day of the casting of the concrete. All such rectifications and corrections shall have to be done and completed on the day before casting is taken up.
- n) The supporting brick walls should be smoothed to avoid adhesion or grip of the concrete of the slab with the wall resulting in cracks in the wall due to contraction and shrinkage stresses developed when setting. This may be done by plastering the top surface of the wall and net cement finishing and properly curing with water and then placing polythene sheet on the top before laying concrete.
- o) For important work, vibrator should be kept ready for vibrating the concrete.
- p) Shuttering shall be properly wetted before laying of concrete.
- q) Opening for fixing W.C. pans, pipes, clamps for fan hooks may be kept in the forms before casting concrete, so that the concrete is not to be partially dismantled and disturbed afterwards.
- r) An officer not below the rank of Sub-Divisional Engineer shall approve in writing the form work, reinforcement detail, the quality of cement, sand and coarse aggregate at least one day before casting work is started.

16.13 MIXING OF CONCRETE

- a) All concrete shall be mixed in a mixer machine unless otherwise approved by the Site Engineer. Every batch shall be mixed in accordance with standard specification and shall be subject to rejection if not conforming to specification.
- b) All concrete shall be mixed thoroughly until there is a uniform distribution of materials and shall be discharged completely before the mixer is recharged.
- c) Every batch shall be mixed for at least 90 seconds or until a uniform consistency of the mixture is obtained.
- d) Platform where concrete shall be unloaded and the drum of the mixture machine shall be cleaned at regular intervals.
- e) The volume of concrete mixed in each batch shall not exceed the manufacturers rated capacity.
- f) A detail record shall be kept to identify :
 - i) No. of batches produced
 - ii) Proportion of materials used
 - iii) Approximate location of final deposit in the structure
 - iv) Time and date of mixing and placing
- g) Remixing of concrete shall not be permitted and any concrete mixed and not used within half an hour must be discarded. Mixing which may have undergone initial setting must also be discarded.

16.14 HANDLING AND PLACING OF CONCRETE

A most thorough and careful design can be completely defeated by improper practices in the handling of ingredients and placing of concrete. Unrestrained dropping, steep cutting and horizontal flow of concrete are extremely harmful and should not be tolerated. Whenever possible concrete should be placed in a form at its final resting place in a structure. Lateral flow of concrete causes the coarse aggregate and the mortar to come to rest at different places in a form and this may result in porous, honey combed or other unsuitable concrete.

In almost all situations concrete should be deposited vertically and in horizontal layers of reasonable depth. Great lift of a simple pour encourages segregation of coarse and sedimentation of the finer constituents of mixtures and moreover may cause unwanted displacement of forms.

No deposition of concrete shall be done before the surface on which concrete is to be poured, reinforcements and forms have been inspected and approved by the Engineer.

Concrete shall be transported from mixing to placing of final deposit as readily as practical while plastic and within the initial setting time, so that it flows readily into spaces between and around reinforcement. Partially hardened concrete shall not be deposited. Retampered concrete or concrete that has been remixed after initial set shall not be used.

After concreting is started, it shall be carried on as a continuous operation until placing of a panel or section is completed. During pouring of concrete, the mason shall not be allowed to use his mug and water.

Concrete shall be deposited continuously in layers not exceeding 12" or of such thickness that no concrete will be deposited on concrete which has hardened sufficiently to cause formation of seams and planes of weakness within the section.

In order to secure full bond at the construction joints to the surface of concrete already placed including vertical and inclined surfaces, shall be thoroughly cleaned of foreign materials and laitance and slightly roughened. Shortly before new concrete is deposited, the joints shall be saturated with water. After free water disappears, the joints shall be given a thorough coating of neat cement slurry to the consistency of a heavy paste. New concrete shall be deposited before the neat cement dries.

The concrete in R.C.C. slabs shall be laid to proper thickness. To achieve this two strips of concrete about 6" wide and a little over the specified thickness should first be placed 6'-0" to 8'-0" apart, compacted and levelled to the exact thickness. Concrete is then poured within the intervening space between the strips (locally known as patta) and properly compacted to the desired thickness.

Care shall be taken that during concreting, the rods are not displaced and that the effective depth of the slabs and the beams, the spacing of the stirrups and rings and the clear cover to the bars are maintained. Care shall be taken to see that the top negative rods are not displaced at all which seriously affects the design and the desired strength of the structure. Particular attention shall be given to the spacing and placing of rods in the cantilevers.

To ensure the above, the following procedures among others in practice shall be adopted :-

- a) Wooden block with handle shall be placed on the shuttering to check the depth of casting.
- b) Before and during casting, the main reinforcing bars both positive and negative shall be kept in position. Negative reinforcement shall be kept in position with steel chairs. Adequate precautions against displacement and depression of rods due to trampling of the workers, shall be taken. If the rods are displaced, these shall be reset to their correct position and tied rigidly again before concreting can be done.
- c) For maintaining the correct clear cover of the bottom reinforcement in the slabs & beams, concrete blocks of proper size should be used and these may be incorporated in the casting. Care must be taken so that no wooden block or any other foreign stuff remains within the concrete mass. Pieces of bricks must not be used as clear cover blocks. To avoid exposure of reinforcing bars and subsequent corrosion due to oxidation, special care shall be taken so that design clear cover is maintained properly.

Care must be taken so that the lines of rods are straight and parallel to the edges of the slab in both the direction. The ends of the rods shall have uniform clearance to the formwork.

Walking on recently poured concrete shall not be allowed. In unavoidable circumstances wooden planks may be laid on concrete for the purpose.

16.15 COMPACTION OF CONCRETE

Concrete shall be thoroughly consolidated by suitable means such as tamping, rodding and spading and shall be thoroughly worked around reinforcement and embedded fixtures and into corners of forms. This is essential for the elimination of large casual voids, the complete encasement of reinforcement and the proper contact of concrete with form faces and embedded fixtures. Compacting is achieved by hand tamping with a variety of hand tools but now more commonly and successfully with power driven vibrators.

Proper use of mechanical vibrator is beneficial to the compressive strength and bond strength between concrete and steel. But the consistency of concrete to be vibrated as measured by its slump should not exceed 3 inch. Internal type vibrators, immersed in concrete, shall be used.

Concrete shall be rodded thoroughly, so that proper density is obtained and no honeycombed surface appears after the removal of formwork. Where beams are deep and where spacing of rods allows, wooden bargahs $2\frac{1}{2}$ " square and about 5'-0" long shall be used in addition to the M.S. Rods for compacting the concrete.

Tamping on the laid concrete in slab shall be done with fairly heavy wooden straight edges (patta) fixed with handle by two masons at either end till the level of the finished surface is attained, proper compaction made and laitance comes out on the surface. Wooden mallets shall also be used for obtaining a uniform compaction and for filling up depressions.

While using mechanical vibrators for compaction of concrete the following precautions shall be taken :-

- 1) The vibrator shall be applied at the point of deposit and the area of freshly deposited concrete. The vibrators shall be inserted and withdrawn out of the concrete slowly. The vibration shall be of sufficient duration and intensity to thoroughly compact the concrete but shall not be continued so as to cause segregation. Vibration shall not be continued at any one point to the extent that localized areas of grout are formed. Application of vibrators shall be at points uniformly spaced and not further apart than twice the radius over which the vibration is visibly effective.

Vibrator shall not be applied directly or through the reinforcement to sections or layers of concrete which have hardened.

Vibrators shall not be used to transport concrete in the forms.

Vibrators in the running conditions shall not be allowed to rest on reinforcement which extends to concrete that has partially hardened.

16.16 SURFACE FINISHING

Concrete surface shall be made smooth and levelled and brought to proper grade.

Steel trowel finish shall be made for exposed floor slab and roof slabs without lime terracing.

Wood float finish shall be done for all slabs to receive lime concrete and brick paving.

Broom finishing shall be made for all slab to receive artificial patent stone, terrazzo flooring, using wire brooms after the concrete is partially set.

Plastering to the concrete surface, where necessary, should be done immediately after the removal of formwork before concrete dries up and hardens.

16.17 CURING

Curing means preventing or delaying up of intrinsic moisture inside the capillaries of concrete for adequate hydration of cement in the mix in order that concrete may continue to gain strength. Curing also helps against shrinkage cracking in plastic as well as in hardening concrete.

Directly after concrete has been placed in the formwork, water begins to evaporate from the fresh concrete surface. If this evaporation is not prevented, plastic shrinkage cracks and surface porosity will develop. It is therefore important to protect the concrete surface against drying out as soon as placing and compaction have been completed and before the water shine disappears completely.

The following are the main methods of curing :

a) Retaining Formwork

This method is useful for curing vertical surfaces of structural elements like walls or columns or ceiling of floor slabs. Formwork used for casting concrete are normally, kept in place for four to seven days and they afford good protection against heat, wind, rain and cold. Wood left in place furnish good protection. To aid curing forms should be oiled and wetted before casting and may also be wetted during hardening.

b) Covering concrete surfaces with wet material

This is the most widely used method. It is done by covering the concrete surfaces by wet hessian, which should be continuously kept wet. Normally for the first 24 hours, the concrete, is protected by formwork. In structural concrete, formwork supporting the vertical surfaces are sometimes struck off after 24 hours. These surfaces such as those of columns and walls are then kept moist by surrounding it with hessian cloth. Horizontal surfaces such as those of road-slabs, house slabs, etc. are covered by wet hessian, damp sawdust or straw. The frequency of wetting depends upon the temperature, velocity of wind, humidity etc.

Ponding method

This is the most efficient method of curing. For the first 18 to 24 hours, the exposed surface is covered with moist hessian or canvas. After that small banks of dykes of clay or lean mortar are built around and along the slab, dividing the slab into number of rectangular ponds. These ponds

are filled with water. This method is suitable for the construction of floors, roof slabs, roads and airfields.

16.18 EMBEDDED PIPES AND CONDUITS

The contractor shall co-ordinate with all other trades in placement of pipes, conduits, equipments and other accessories and shall provide the necessary openings in the concrete slabs. Concrete shall not be poured before placement of pipe and other concealed service lines.

The piping shall be so fabricated and installed that it will not require any cutting, bending or displacement of the reinforcement from its proper location. If any bending or displacement is required the attention of the Engineer shall be drawn for his decision.

All pipes, conduits or fixtures required to be embedded in the concrete shall be placed and secured in position before casting is commenced.

Special care shall be taken in case of conduit pipes for electrical wiring so that it is not laid in the slab below the bottom reinforcement, which shall invariably result in cracks in the slabs. These pipes shall be placed between the top and bottom reinforcements. Placing of conduit pipes parallel to the main reinforcement shall be avoided as far as practical. Conduit pipes shall be placed diagonal to the reinforcement as far as practical to avoid cracks in the slab.

For the purpose of payment no deduction shall be made on account of displacements of concrete by pipes, utilities and other embedments and reinforcements unless otherwise specified.

Conduits and pipes of aluminum shall not be embedded in structural concrete unless effectively coated or covered to prevent aluminium concrete reaction or electrolytic action between aluminium and steel.

Conduits, pipes and sleeves passing through the slab, beam or wall shall not impair significantly the strength of the construction.

Conduits and pipes with their fittings, embedded within a column shall not displace more than 4 percent of the area of cross section on which strength is calculated.

Conduits shall not be larger in outside dimension than $\frac{1}{3}$ rd the overall thickness of slab, wall or beam in which they are embedded.

Conduits shall not be spaced closer than 3 diameters or widths on centre.

16.19. FORMWORK AND SCAFFOLDING

Forms are intended to define the contour and locate the position of individual members with reference to the structure, as a whole. Forms shall result in a final structure that conforms to shape, line, dimensions of the members as required by the design, drawings and specifications. To limit satisfactorily the size, shape and position of parts of the structure, it is necessary that forms be built to resist the forces imposed upon them.

All forms shall be of wood or metal as specified and shall be built mortar tight and of sufficient rigidity to prevent distortion due to the pressure of the concrete and other loads incident to the construction operation. Forms shall be constructed and maintained so as to prevent warping and the opening of joints due to shrinkage of the timber.

The form shall be substantial and unyielding and shall be so designed that the finished concrete will conform to the proper dimensions and contours.

Forms shall be so constructed that it can be dismantled without causing damage to the concrete or disturbing the centering and shuttering of other elements.

The formwork shall be water tight specially for the roof slab. Bamboo matting may be placed on planks or steel sheets to provide a rough surface after stripping of the formwork. Alternately ceiling may be roughed up by chiseling immediately after stripping off the formwork.

Suitable camber shall be provided in the formwork for horizontal members. The camber for beams and slabs shall be 1 in 250 and for cantilevers 1 in 50 of the projected length.

Scaffolds shall be made from strong and suitable bamboo poles, wooden post or steel pipes. They shall be adequately tied to vertical member resting on firm floor.

Strong ropes shall be used to tie up bamboo poles. Bamboo for vertical supports shall not be less than 75mm in diameter and shall be straight as far as possible. Bamboos may be used as vertical support for upto a height of 4m if horizontal bracings are provided at the centre. Splicing shall not be allowed. Good, sound and uniform bamboos shall be collected in sufficient quantities for providing scaffolding, providing temporary stage etc. The bamboos shall be free from any defects. Joining bamboos with only nail shall be prohibited. Steel centering frame may be used for any height. In case of patented materials, the instruction of the manufacturer regarding the load carrying capacity shall be followed. Post to post support shall be provided with wooden planks. When tubular steel and timber centering is to be used in combination necessary precaution shall be taken to avoid any unequal settlement.

Tubular steel centering shall be thoroughly inspected before erection. Defective members shall be discarded. Adjustment screws shall be set to their approximate final adjustment after assembling the basic unit and the unit shall be levelled and plumbed.

The centering frames shall be braced to make a rigid and solid unit. Struts and diagonal braces shall be in proper position and secured. As erection progresses, all connecting devices shall be in place and fastened for full stability of joints and units.

In addition, cross bracing with bamboo or wooden posts shall be provided alongwith tie or guys of steel wire or rod not less than 6mm.

Wooden planks or steel sheets shall be placed across horizontally below bamboos or wooden post to provide suitable footrest and carry construction materials. The whole assembly shall be securely lashed together.

The props shall be placed on timber planks, false brick work or steel sheet covering several posts at a time so as to eliminate the possibility of any sinking of the earth below particularly when the earth is likely to be moistened by water.

Care shall be exercised that centering of columns are true to plumb and thoroughly cross braced to keep them in position.

Due attention shall be given not to disturb the top layer of brick work at the time of fixing the shuttering. If this happens, the top coarse should be replaced by fresh brick work.

The shape, strength, rigidity, water tightness and surface smoothness of reused forms shall be maintained at all time. Any warped or bulged timber must be resized before being reused. Forms which are unsatisfactory in any respect shall not be reused.

Half seasoned soft wood, laminated board or other smooth sheet shall be used for formwork for a fairfaced finish.

The formwork made of materials liable to absorb water shall always be sprinkled with water to prevent water absorption from concrete. Water shall not be profusely used and the formwork shall be in a saturated surface dry condition.

All forms shall be tested both individually and in combination before final use to detect any flaw or defect. Measures shall be taken immediately to remedy any fault, if detected, before the formwork is ready for use. The frame and its joints shall be checked from time to time for the decay in ropes, bamboos, planks etc. The defective parts shall be replaced before the formwork is used.

Scaffolding and formwork shall be checked to see if all the props are stiffly supported over the firm base. If any form is found off base, wooden edges shall be inserted below the prop to obtain the required degree of rigidity, with regard to horizontal movement. Pieces of planks shall be used under each prop to distribute the load to a sufficient area of the ground.

The props should be adequately braced and their spacing shall not be more than 2'-6" square below R.C.C. slab centering. Very strong bamboos or saibullah props shall be used for the shuttering of R.C.C. beams.

No clay plaster, packing with pieces of paper, jute, cotton waste etc. shall be allowed to make up the gaps between the centering.

Metal ties or anchorages like bolts and nuts within the forms in vertical members shall be loosened and withdrawn before initial setting of concrete. The resulting hole shall be filled with rich mortar and the surface left smooth, sound, even and uniform in colour.

Forms shall not be removed until the concrete has developed sufficient strength to support all predicted loads.

Form shall be removed in such a manner as to ensure the complete safety of the structure.

For all R.C.C. work with proportion 1:1½:3 steel shuttering shall be used.

An officer not below the rank of Sub-Divisional Engineer, shall check all reinforcing details and levelling of the centering. In case of slab supporting on brick work, the top level of the brick wall shall be levelled either by a levelling instrument or water level and shuttering shall be levelled with respect to the top of the brick work.

The form shall not be removed before the expiry of the minimum period specified below :

- | | | |
|--------------------------------------|---|---------|
| 1) Bottom of the slabs | = | 15 days |
| 2) Bottom of the beams & girders | = | 21 days |
| 3) Sides of the beams | = | 7 days |
| 4) Sides of the columns | = | 3 days |
| 5) Sides of the pedestals & footings | = | 2 days |

PLASTERING**17.1 SCOPE**

The work covered by this item consists of providing plaster of any specified thickness and proportion on surfaces of brick work and concrete for protection of masonry surface and concrete and also for giving an aesthetic appearance.

17.2 SURFACE PREPARATION

Before commencing plastering work, all drawings, finishing schedules will have to be checked thoroughly to identify the surfaces receiving the particular type of plastering.

All concealed utility service lines, conduits, pipes, clamps, door/window frames and other such inserts must be in position before plastering commences. Chiselling and patch repairing of plastering shall not be permitted.

All joints of masonry shall be raked out to a depth of 10mm.. All brick faces shall be made free of dust, cement mortar, algae, moss, dirt etc. by washing with water. The surface shall also be soaked with water before plaster is applied.

When a flat smooth surface such as ceiling or a surface of exposed concrete is plastered, the surface shall be roughened beforehand by picking thoroughly with a suitable sharp picking tool and also be watered.

17.3 MATERIALS

Cement shall be Ordinary Portland cement Type 1 and sand shall be as specified in the schedule of rate. Mix proportion for wall shall be 1:6 and for ceiling 1:4. Sand shall be screened by a 100 mesh wire netting sieve and washed to get free from clay and other salts. It shall be carefully washed in water to get rid of the trouble of saltpetre action in plaster and dampness to the wall due to efflorescences. The mortar for plaster should be mixed dry in the proportion as specified and wet mixing shall be in small quantity to avoid initial setting of cement before it can be used up. Mixing of mortar on a finished floor must not be allowed.

17.4 APPLICATION METHOD

Before the application of plaster, the surface shall be soaked with water so that water from the mortar is not absorbed by the dry surface. The cement and sand properly mixed with water in the proportion as specified shall be laid on the clean walls to a thickness of 12mm. Thicker plaster on average upto 20mm. may be necessary for the uneven face of the 250mm. wall. Laid plaster shall be finished by straight edge and trowel. Adequately long straight edge shall be used to bring the surface to true plane and level. After finishing the plaster with trowels and after some hours steel

trowel (USHA) shall be used to make the plaster smooth. Care should be taken to see that Usha is not used just after laying of the plaster when it is too soft. Neither should it be used after it has completely hardened up. It should be used after the plaster has commenced to set, so that there is no mark of Usha in the plaster for obtaining a perfectly smooth surface having no undulation.

Guide bunds of plaster called the 'Paya' first be laid on the wall at suitable distance and their verticality and their being in the same plane shall be checked by a wooden straight edge (patta) and plumb bob. Then the space in between shall be made even by laying the plastering materials and finishing the surface evenly between the guide bunds. The surface and levels of plaster should be checked by placing the straight edge horizontally, vertically and at different angles.

When a flat smooth surface like ceiling is to be plastered, the same method shall be applied but the thickness shall be only 6mm. The use of 'Usha' in the ceiling plaster is very important as this is the only way how the ceiling plaster can be conveniently made smooth and even. It should be remembered that the lack of attention on this point shall give a poor finish to the ceiling, leaving trowel and uneven 'Usha' mark which speaks seriously on the aesthetic look and the finish of the room. Particular attention shall be given to this by the field officer.

Another way of checking the level of ceiling plaster is by high powered electric light. Unevenness of plaster in the ceiling will be clearly visible if high power bulb is lit in the room. Level of ceiling plaster can also be checked by spraying water on the ceiling and checking the movement of water drops on the ceiling. On a level surface of ceiling water drop shall not move horizontally, rather it will stay at one point or fall on the floor. While on an uneven surface, water drop tends to move towards the lower levels.

A full wall or ceiling of a room will preferably be completed at a time.

Corner and edges shall be slightly rounded up but the corner in the junction of wall and roof, wall and floor and junction between walls shall have either straight edge or uniform curvature as desired by the architect.

17.5 CURING

Curing of plaster shall be done for 7 days. Brass hand sprayers or water pipes shall be used for curing plastered surface. Care shall be taken to see that the plastered surfaces are kept wet for at least 7 days. For want of curing, plaster becomes weak even though right proportion has been used.

17.6 PRECAUTION

- a) Utmost care shall be taken to the correct and smooth finish of plaster without which the surface and the building presents a very poor show. Edges and mouldings must be true to line and level.
- b) Sand shall be well screened and thoroughly washed in water for getting out of foreign materials and undesirable salts.
- c) Care shall be taken to avoid trowel and 'usha' marks and depressions and holes on the surface.
- d) Sand and cement shall be mixed very thoroughly in dry condition before water is applied and in no case the quantity mixed should be for more than $\frac{1}{2}$ hour's use. Mixing in big quantity shall be avoided.
- e) Special care shall be taken for curing.

LIME TERRACING**18.1 SCOPE**

The work covered by this item consists in providing a terrace roofing of lime concrete of mix proportion 2:2:7 by volume. Lime terracing is provided to cover the R.C.C. roof for its protection against the ravages of sun and rain and also to provide slope for drainage of roof water. Lime terracing also stops soaking of water when it rains for a good number of days. The covering consists of a slab of lime concrete over the R.C.C. roof made of Khoa, lime, surki, the proportion of 2:2:7 by volume. The normal thickness is 100mm., 75mm. to 87mm. may also be done in small sized roof.

18.2 MATERIALS

1. Lime
2. Surki
3. Brick chips.

Lime shall not contain more than 5 percent of foreign impurities. Store lime shall first be slaked for 48 hours, then strained through a sieve of 64 meshes to a sq. inch. It shall dissolve in soft water when this is added in sufficient quantities.

Surki shall be made from well burnt 1st class brick bats but not vitrified brick bats. Surki made from under burnt or 3rd class bricks shall not be used. Surki shall be perfectly clean, free from admixtures of dust, sand or any other particles and shall be grounded to such fineness as would pass a seive of 64 meshes to square inch.

Brick aggregate shall be from well burnt 1st class bricks or from same bricks broken into pieces. The size of the aggregate shall be below 25mm. Brick aggregates shall be continuously soaked with water for 7 days before use.

18.3 MIXING

The required quantity of khoa measured by volume shall first be laid and spread on a pucca platform in uniform thickness. The requisite quantities of lime and surki measured by volume shall be mixed dry on a separate platform by turning over the materials, several times till a uniformity of colour is obtained. The mix is next spread out evenly over the previously laid quantity of brick aggregate. The whole mass is mixed together gradually proceeding from one edge and continuing for the whole area.

When the khoa has been mixed up with lime surki mix, uniformly all over, clean water shall be added gradually and the mixing shall be done until a uniform consistency is obtained. The mixture shall be kept wet and turned over twice a day for at least five consecutive days before being carried to the roof. It must be confirmed that the mixture has attained desired consistency and lime has fully been slaked before carried to the roof. Care shall be taken to keep it under cover to protect it against rain and the sun.

16.4 SURFACE PREPARATION

The roof deck on which the lime concrete will be laid shall be clean of all dirt, waste and other loose materials. Loose layers of concrete mortar shall be cleaned thoroughly using chisel hammer, scrapper, wire brush etc. as required. After cleaning, the roof shall be washed with water.

16.5 INSTALLATION

After the mixing of lime concrete is completed and tested for its suitability for laying, the concrete shall be carried on the roof top and laid on the roof to proper slope and grade. Before laying the mixture, tramping of lime shall be Spain hold on the roof surface.

The thickness of the concrete shall be based on roof area and the quantity of run off of the expected rain water. The mixture shall be laid at least 1 inch more than the beaten thickness according to the grades and slopes as shown in the drawing.

Lime concrete thus laid shall be consolidated by tamping with wooden thappis always maintaining the proper slope. Slope shall be minimum 1:20. Beating shall be done by group of workers sitting in a row who will traverse the length of the roof backwards and forwards beating with wooden mallets. Tamping shall be continued for 7 consecutive days till mortar comes to the surface. Full compaction will be considered to have been attained when the wooden mallet when struck on the surface rebound with a metallic sound. The surface will be kept constantly wet when it is being beaten by lime water to which molasses are added 250 grams to a gallon of water. The concrete shall not be allowed to be dried up until the compaction is complete. The mortar which comes to the surface of the terrace during the beating is to be rendered smooth and finished off by rubbing the surface with a slurry made of lime and surki (1:2) mixed with water with the help of steel trowel (USHA) to bring the surface to a very fine polish.

When lime concrete roofing can not be laid in one day, each days work shall be terminated on a straight line with a 1:2 side slope. Joining of the new work to previous day's work shall be accomplished by applying a bonding grouting of lime surki mortar 1:1 to the slope before placing the new lime concrete.

Lime concrete shall be extended upto 125mm of the end brick parapet wall of 250mm and 250mm for 275mm wall, leaving a gap of 125mm only to be filled by in a layer of brick set in cement mortar 1:3. If there is no parapet the lime terracing shall be finished in such a way that the rain water would easily pass over 125mm brickwork. If a parapet is to be provided in a building, it should be at least 250mm of two layers and then 125mm with 250mm pillar or 250mm to the full height, so that the brickwork fully covers the lime concrete, giving no chance of leakage or soaking by rain water. The junction of roof and wall is to be provided with a triangular bank of lime concrete well beaten, commonly known as "Ghundi". The size of the ghundi will be 75mm on the roof and 125mm on the parapet. For passage of rain water gaps should be kept under the parapet to be connected with spouts or rain water down pipes. For every 375gm sft of roof area the 100 mm dia of rain water pipe or spout is necessary.

The concrete shall be kept covered by putting a 75mm thick layer of straw over it and be cured by wetting this by spraying water for a period of 15 days.

The surface shall be brought to a very fine polish by rubbing with a fine smooth trowel and to assist in this fine lime putty may be used sparingly.

18.6 FIELD TESTING OF COV PACTION

Well compacted and properly mixed and laid lime concrete when beaten by a wooden mallet shall give a metallic sound.

The final compaction of the lime terracing roof shall also be tested by cutting a small portion of the material 75mm square and 50mm deep in a few representative areas and pouring water there in and observing for half an hour. If there is no percolation of water inside the concrete and there is no depression in the water level the compaction and impermeability of the lime concrete will be considered to have been adequate. If otherwise the lime terracing shall have to be done again.

18.7 PRECAUTION

1. Field test shall be conducted to check the compactness of lime concrete.
2. The mixing of lime, surki and brick chips must not be done on the roof but invariably on the ground on a brick platform. Lime and surki shall be mixed dry separately and then laid evenly on the privations by laid brick chips.
3. Mixing of lime concrete shall be considered adequate if it forms lumps and does not disintegrate when attempt is made to form a lump.
4. If there is a parapet on the roof, providing ghundi is a must to avoid leakage at the junction of roof and parapet

WHITE AND COLOUR WASHING**19.1 SCOPE**

The work covered by this item consists of providing a plastered wall or ceiling with one or more coats of washing with lime to which gluing materials and small quantity of blue is added. In color washing, a color pigment is added to the lime water mix.

19.2 MATERIALS

- a) Quick or stone lime
- b) Gum Arabic
- c) Robin blue
- d) Color pigment
- e) Water

19.3 MIXING

Stone lime shall be slaked on the spot. The slaked limes shall then be placed either in a tub or any other container containing clean water. It shall be mixed and stirred thoroughly until it attains the consistency of thick cream.

The mixer thus prepared shall be allowed to rest for about 12 hours. The floating foreign materials are removed from the top surface. The mix is then stirred thoroughly for about 10 minutes.

When sufficiently mixed, it shall be strained into a separate container through coarse cloth. Gum Arabic in the proportion of 250gm of gum to 20kg or 1 cft. of lime shall be added and dissolved in the strained mix. A small quantity of Robin blue is also added to mix as desired by the Engineer to give a slight bluish tinge.

Color pigment according to colour schedule or as directed by the Engineer shall be added to the mix in case of colour wash.

Requisite quantity of water shall then be added so as to produce a slurry of the required consistency. It shall be stirred sufficiently to ensure uniform mixing. It will then be ready for use.

19.4 SURFACE PREPARATION

Before the white wash is applied the surface of the wall or ceiling shall be thoroughly cleaned and free from all foreign materials. Defects shall be repaired accordingly. If necessary it shall be rubbed with sand paper.

Before application of white wash sample work shall be done on selected surfaces for the approval of the Engineer. In case of colour wash this is more important to select the right shade as desired by the Engineer or Architect.

19.5 APPLICATION METHOD

White wash shall be applied on the surface in two coats over a coat of priming. Each coat of washing shall consist of two courses, one applied vertically and the other horizontally.

Each coat shall be allowed to be dried up perfectly before a succeeding coat is applied over it. In case of colour wash, priming coat shall be white.

Whatever scaffolding is necessary for white wash, it shall be free standing so that it can not damage or scratch the painted surface.

The final coat shall be laid on with hair brush and not with brushes made of jute. The final coat shall be perfectly smooth, free from any marks of brush or others.

19.6 PRECAUTION

- a) Before application of the white wash or colour wash, the floor surfaces and dado of walls shall be kept moist so that the white wash or colour wash dropping marks can be easily cleaned. If the surface is dry it becomes very difficult to remove the stain. In important surfaces, it should be covered with hessian, so as to eliminate dropping of white wash on those surfaces.
- b) After the days work, the surface of the dado and floor of each room and verandah shall be thoroughly washed with water and cleaned by rubbing.
- c) Any white or colour wash dropping on the wood works of doors and windows, ventilators, partitions, shall be removed by rubbing with a piece of wet cloth and washing with water. Such marks on painted surface should be washed and finished with oiling, if necessary.
- d) Quantity of colour wash shall be mixed at a time in such a way that one room or a wall surface which is visible at a time can be completed, in order to ensure uniform colour throughout.

DISTEMPERING AND PLASTIC PAINT

20.1 DISTEMPER**20.1.1 SCOPE**

The work covered by this item consists of finishing the plastered surfaces with two coats of synthetic polyvinyl distemper applied over a prime coat of chalk wash with glue or sealer. This is exclusively for interior decoration and the distempered surface is non-washable.

20.1.2 Materials

- High quality SPD of approved Brand
- Shell lime
- Whiting
- Putty
- sealer
- Clean water

(No distemper, the make of which has not been approved by the Executive Engineer shall be used. Whiting is made by reducing pure white chalk to a fine powder.)

20.1.3 Surface preparation

The surface to receive distemper shall be thoroughly rubbed with sand paper, to be made free from all dirt, grease, loose paint and other foreign materials. If necessary, the surface shall be washed with water and dried. If during this process, any part of the old smooth surface gets damaged, it shall be repaired and the plaster applied so that the surface of the new work lies evenly with the old. Any depressions, holes in the plaster shall be repaired with approved putty.

After the repaired patches are thoroughly dry, the wall shall be washed over twice with a solution made from equal proportion of whiting and best shell lime. Distemper is applied upon the base thus prepared.

Sample of distempering work shall be done on selected surface for approval of the Executive Engineer before final application.

20.1.4 Mixing and application

Only proprietary distemper shall be used and the manufacturers instruction for mixing and applying them must be followed.

Distemper paste from the sealed container shall be dumped in a separate container. Quantity of water as per manufacturer's instruction shall be added in the same container and stirred and mixed until it attains the desired consistency.

Distemper shall be applied on the surfaces by proper distemper brushes so as to leave no mark. The brush shall be dipped in the mix and stroked on the walls horizontally. The mason shall work in such a manner that no overlap is visible when the surface is finished.

Each coat shall be perfectly dry before the succeeding coat is applied over it.

Two coats of distemper shall be applied over the prime coat.

20.1.5 Precaution

1. Only approved brand of distemper shall be applied.
2. Whatever scaffolding is necessary, it shall be free standing and not to damage or scratch the painted surface.
3. Adequate precautionary measures shall be taken so as not to damage or stain the floors, walls or any other work while applying distemper. Any damage, stain or spots caused while distemping shall be rectified and removed instantly.
4. The thinned material shall not be kept longer time for menses

20.2.0 Plastic paint

20.2.1 Scope :

This paint is used both for interior and exterior decoration. The printed surface is easily washable with soft soap and water.

20.2.1 Materials

- High quality plastic paint of approved Brand.
- Putty
- Sealer
- Clean water
- Whiting
- Shell lime

20.2.2 Mixing

Mixing shall be as per manufacturer's specification and approved procedure.

20.2.3 Surface preparation, application and Precaution

Surface preparation, application and precaution shall be same as stated in case of distemper.

**PAINTING, VARNISHING,
COALTARING, OILING****21.1 PAINTING****21.1.1 Scope**

The work covered by this item consists of painting wood works of doors and windows and iron and steel work in door and windows, steel trusses, grills, gates etc. and varnishing, coaltaring and oiling wood works.

21.1.2 Materials

1. High quality synthetic enamel paint of approved Brand
2. Sand paper.
3. Putty:

Made of 2 parts of whiting (absolutely dead stone lime) 1 part of white lead, mixed together in linsed oil and kneaded (OZ linsed oil to 1 lb of whiting will do) with wooden mallets until thoroughly incorporated. After kneading it is left for 12 hours when it is kneaded again to give smooth workable paste. Desired pigments could be added if coloured putty is needed.

4. Thinner

Spirits of turpentine is the most commonly used thinner. It is inflammable, evaporates rapidly. Use of thinner in excess in paint reduces the protection value of the coating, flattens the colour and lessens the gloss of the linsed oil. At the most 5 to 8 percent thinner may be used. When warmed gently, turpentine shall not have smell of resin or coaltar, when shaken vigorously it should not froth, on evaporation it should not leave any residue and paper coated with turpentine and left to dry should remain unstained and should then taken freely. Thinner shall be used of the same Brand as of the Brand of painting.

Before purchasing the materials the contractor shall submit list showing the brand, name and type of paints proposed to be used for the work. Manufacturer's catalogue, specification sheet, expiry date of use shall be submitted to the Engineer for approval.

No material shall be used without approval of the engineer. All rejected materials shall be removed from site immediately.

All painting materials shall be of the best quality and be delivered to the site in Sealed original container bearing approved manufacturer's level.

Materials to be used in the work shall conform to BSI standards and reputed manufacturer's specification.

21.1.3 Storage

Materials and tools shall be stored in a single place at the site.

Storage area shall be maintained in a neat and clean condition with surroundings protected from dampness and damage.

Inflammable materials shall be stored in sealed containers, waste shall be removed at the end of each day. Every precaution shall be taken to prevent fire.

Storage area shall be accessible to the Engineer at all time.

21.1.4 Colour and Sample

Before application of paint to wood, steel or any other surface, samples shall be prepared as directed on a piece of same kind of materials upon which the paint shall be applied. Colour and sample may be varied until it is approved by the Engineer.

21.1.5 Protection

Rough cloths or other approved protective materials shall be furnished and laid in all areas where painting and finishing is being done so as to adequately protect flooring and other work from damaging during execution of painting work. Under no circumstances paints shall be allowed to spit on floors, specially mosaic where stains shall be almost impossible to remove.

21.1.6 Surface preparation

21.1.6.1 Wooden surface

Whole success of painting operation depends upon satisfactory preparation of the surface to be painted and the great majority of defects which occur are due to faulty preparation. Wood work shall not be painted unless it is absolutely dry. It shall also not be done in the monsoon months. Before applying, the wood work must be roughly cleaned and all projection removed. Knots and holes, if any, shall be filled using filler made with a mixture of red lead and glue in equal quantities called knotting, compatible with the finishing specified and tinted if required to camouflage repairs. Nail holes, cracks and other inequalities shall be filled up by stopping to bring the surface to a level with glazing, putty. Glazier putty is also called ordinary putty. It is a paste of very thick consistency which is applied to fill up holes, cracks before applying a paint.

Dry wood work shall be brought to a smooth and even surface by rubbing it with sand paper of different grades from coarser to finer ones.

21.1.6.2 Works Iron and Steel

The finishing of iron and steel works in building is one of the most important aspects of the finishing of building because iron and steel are subjected to reduction by corrosion. Generally the application of any coating, lining materials, adhesive or paint requires its first essential, a perfectly clean surface. This is of very great importance while dealing with the painting of iron and steel. Any paint coat applied on greasy or oily steel surfaces will lack proper adhesion and will lead to failure of the paint film. Removal of rust and millscale is more difficult but of equal importance. A good all purpose degreaser is mineral turpentine oil. Oil and grease can also be removed by gasoline or benzine but should be carefully handled because of its inflammable character.

Corrosion is generally more rapid and severe in hidden places and pockets where water and rubbish collects.

Before painting rust scales and dirt should be removed by means of iron brushing, scrapers or other effective methods. Bristle and wood fibre brushes can be used for removing the loose dust. Special attention should be given to the cleaning of corners, reentrant angles, weld spatters.

Iron and steel work must be thoroughly dry before being painted.

After the preparation of iron and steel surfaces and prior to the application of decorative cover, the first primer coat shall be applied. The primer coat may be red lead paint or red oxide primer. The correct timing of the application of the primer coat is a very important factor particularly when

humidity is high and dew settles on surfaces in the evening or night. Roughly speaking painting of steel work can be started at about 10. A. M. which is generally the time when all dew has evaporated. Thinner shall not be added to the primer on the pretext that consistency of the paint supplied by the manufacturer is too thick. A minimum of 2 coats of primer paint should be applied specially in the case of those primers where pigment themselves have rust inhibitive property.

After the application of the primer coats, an undercoating is often recommended to be applied prior to the application of the finishing coats. The object of the undercoating is to provide a heavy pigmented layer that will give full bodied colour in conjunction with the finishing coat-but from protective point of view, two finishing coat is better than one under coat and one finishing coat.

All beams and trusses in roof work shall be coated with the priming coat before erection. All damages to shop coating caused during erection, repairing and cleaning shall be spot primed with the same material used for the shop coat.

If any steel member is to be encased by concrete, it shall be painted with a coat of cement slurry.

21.1.6.3 Galvanized metal

Galvanized iron should not be painted until it has been exposed to the weather for a year as paint adheres badly to new galvanized iron. If it is necessary to paint earlier, the surface shall be washed with vinegar or slaked lime and washing soda before painting. Before application of paint, grease or oil films shall be removed by solvent using coarse cloth. Painting shall be applied only when the galvanized metal is perfectly dry.

21.1.7 Application

No work shall be done under conditions which are unsuitable for the production of good result. All spaces shall be broom cleaned before painting or finishing is started.

The workmanship shall be the best, materials shall be applied strictly in accordance with manufacturer's direction and in particular no prepared paint shall be thinned in any way except as directed by the manufacturer. All paints shall be thoroughly mixed before being used.

No exterior painting shall be done in rainy, damp weather, until the surface is thoroughly dry. No interior painting shall be done on damp surface.

After the wooden surface is prepared priming coat is to be applied. It shall be fairly thick to make the surface absolutely plain to receive the finishing coat. Priming coat is applied to fill the pores of wood or any minute inequalities on the surface to be painted. It also prepare a smooth base for the subsequent coats of paints and accelerates their drying. A priming coat may be given of red lead or of red and white lead mixed in double boiled linseed oil (4 lbs of red lead or 7 lbs of red and white lead mixed with 3/4 gallons of oil). When dry all cracks or holes are filled with putty and the whole surface rubbed with sand paper. Priming coat should not have any turpentine. Knotting shall be done before application of priming coat and stopping after the application of priming coat.

The paint shall be applied with brush and spread as evenly and smoothly as possible. As soon as the whole or a convenient area is covered, the brush shall be passed over the paint in one direction contrary to that in which it is finally to be laid off which is known as crossing. After crossing, it should be laid off softly carefully in a direction contrary to the crossing but along the grain of the wood taking care that none of the iron brush marks be left visible. The brush should be laid into that portion of the work already done, so that the joining may not be perceived.

Every coat shall be perfectly dry and all dust carefully removed from the surface before the succeeding coat is laid over it.

Minimum drying time shall not be less than 72 hours between coats for exterior coats and 48 hours for interior coat paints.

All natural finished wood work, painted wood work and painted metal shall be slightly sand papered between coats using zero paper.

The paint must not be allowed to settle in the cans. To prevent this each painter will have in his can of paint, a small stirring stick with which he must stir up the paint occasionally.

In painting the glazed doors and windows, the pully round the glass panes must be painted and after the completion of final coat, the glass panes shall be cleaned, stains from the paints on the panes being removed by the application of a little turpentine or spirit.

New wood shall receive one coat of priming and 1 or 2 coats of painting of approved colour and manufacturer, as specified in the schedule of items.

All exposed pipes (except PVC) shall be painted according to colour as specified by the Architect or Engineer.

Painting the finished hardware or other removable items already in place shall not be allowed.

Any damage to adjoining surfaces or works caused by painting operations shall be rectified.

Priming coat is to be composed of 10 parts red oxide, 4 parts raw linsed oil, 1 part turpentine, all by weight.

In repair works, old paints shall be washed off with caustic soda and thoroughly rubbed with rough materials and washed finally with soap. For clearing old and sticky paints or for surfaces where paints can not be cleaned by washing, blow lamp may be used for removing old paint.

For painting iron or steel work, one or two coats of red lead or any other approved paint as per schedule of items and finishing schedule will be laid after placing the iron or steel beam and trusses in position. Red oxide of iron may be used in paint on unimportant works.

Care must be taken that painting either on wood or steel work is done with brushes of the best quality. Pieces of cloths or jute shall not be used as substitutes for brushes for painting.

21.1.8 Completion

After completion of painting work, the contractor shall remove any paint spots and stains caused by work under this section from floors, walls, glass, hardware, equipment and other surfaces leaving these surfaces in perfect condition.

The Engineer will conduct a final inspection of all works under this section and the contractor shall repaint or retouch as directed by the Engineer. All surfaces finished under this section shall be left in perfect condition, free of defects and blemishes.

All rubbish and accumulated painting materials shall be removed from the premises.

Contractor must be responsible so that any painting on any surface remain almost the same upto the warranty period.

21.2 VARNISHING

21.2.1 Introduction

The essential component of all varnishes is resin which is dissolved in oils, turpentine or alcohol. The liquid dries or evaporates and leaves a good transparent, glossy film on the varnished surface. There are various types of varnishes obtainable in the market each suited to a specific work.

There are three essential constituents of all varnishes :

1. Resin

Copal is the commonly used resin. It is a hard shining, generally bright yellow or brown coloured resin, found embedded in earth. Besides copal mastic (Rumi mostaki), amber, gum and lac are the other commonly used resins. English copal is considered to be the best. Quality of varnish depends much upon the quality of resin used. Copal is considered to be the best, tough, hard and is very useful for external use.

2. Solvent

These must suit the resin used. Boiled oil is used to dissolve copal or amber, turpentine oil for common resin or mastic and methylated spirit for lac.

3. Driers

These should be added in small quantities as excess quantity injures varnish and impairs its durability. Litharge (lead monoxide) or lead acetate are the commonly used driers in varnish added to accelerate drying process.

21.2.2 Types of varnish

Based on different types of solvents, varnishes are classified as given below :

i) Water varnish

They consist of lac dissolved in hot water with borax, ammonia, potash or soda just enough to dissolve the lac. Varnish so prepared withstands washing. It is used for painting wall paper and for delicate works. The mix proportion shall be Borax 6 ounces, shellac 2 lbs, gum 4 ounces, water 1 gallon mixed together.

ii) Oil varnish

These are made by dissolving hard resins like amber or copal in oil. They are slow to dry but are hardest and most durable of all varnishes. These are suited for being used on exposed surfaces requiring polishing or frequent cleaning and for superior works. If in place of oil, turpentine is used for dissolving the resin, it becomes a turpentine varnish.

iii) Spirit varnish

Shellac varnish and French polish belongs to this class. It is formed by dissolving shellac in methylated spirit. 400 grams of shellac is dissolved in a litre of methylated spirit without heating. It may be coloured by adding pigment. The solution is then strained through a double thickness coarse cloth. A very small amount of plasticizer such as castor oil is sometimes added.

21.2.3 Application

Before applying varnish, the wood surface shall be clean and dry. A coat of thin clean glue with necessary quantity of staining colour consisting of equal parts of burnt umber (brown mineral used as pigment) and burnt sienna shall be applied, allowed to dry and rubbed down smooth with fine sand paper. Varnish should be done in thin coats over this, when dried. English copal varnish is considered the best. For new wood work a second coat of varnish should be applied after the first coat has thoroughly dried and rubbed down with fine sand paper. Each coat of varnish must be rubbed before next coat is applied except the last.

As methylated spirit is used as solvent, French polish dries quicker and becomes hardened and more brilliant than oil varnishes but cracks and scales off. It does not withstand weathering and is used only in superior wood work, not subjected to the vagaries of the weather. Before applying French polish, the surface is cleaned of dust. It is then coated with a filler made by mixing 250 grams of whiting in one litre of methylated spirit. When the filler coat has dried, the surface is rubbed with sand paper.

French polish shall be applied to the prepared wood surface with a polishing pad of soft cloth containing absorbent cotton filling and not with a brush, with quick and light strokes along the grains. Several coats will be necessary before the desired shine and finish is achieved.

French polish is worked upon the surface of hard woods to heighten the effect of grains.

Frequent application of raw linsed oil rubbed in well with rags will give a fine polish to wood work.

The varnish should become surface dry in not more than 6 to 8 hours and hard dry in not more than 18 hours. Good varnish should be dry and free from stickiness within 2 days.

A little quantity of pure mustard oil rubbed over the polished surface when it is almost dry adds to glossiness.

21.2.4 Covering capacity of paint and varnish

The covering capacity of paint and varnish varies according to the composition of paint and varnish, surface to be covered, the human elements in application but the following may be taken as a general guide :

Type of paint	Covering area
One litre lead priming paint	
a) on wood	9-11 sqm
b) on metal	9-13 sqm
One litre flat undercoating	10-12 sqm
One litre gloss paint	9-13 sqm
One litre enamel paint	9-13 sqm
One litre varnish (first coat)	11-13 sqm
One litre varnish (2nd coat)	13-18 sqm

21.3 COALTARING

When appearance is not a governing consideration, sometimes wood or iron surface is coal-tarred. Before applying coal tar on wood or steel, the surface must first be well cleaned and dried.

The mixture shall contain four gallons of coal tar, one gallon of kerosene and eight pounds of unslaked lime heated to boiling point and applied on the surface while hot. If allowed to cool, the mixture will harden, so only a small amount should be mixed and boiled at a time. It should be applied with a brush. Small articles to be coated may be dipped into the hot mixture.

Not less than 10 lbs of coal tar should be used per 100 sft of surface tarred.

21.4 OILING WOOD WORK

One pound of bee's wax mixed with 3 lbs of double boiled linsed oil are heated over a slow fire till the wax is melted. After the mixture has cooled, 1 lbs of turpentine is added. It is then applied to wooden surface. This will cover about 800 sft of surface. Wood work can also be oiled with earth oil to which equal parts of vinegar and turpentine have been added. This gives a darker effect. A mixture of oil and water should never be used.

Only well seasoned wood should be oiled. Oiling unseasoned wood will do more harm than good and will induce dry rot.

The oil will be applied to the wood surface when the surface is perfectly dry.

CEMENT PAINT AND TEXTURED PAINT**22.1 SCOPE CEMENT PAINT**

The work covered by this item consists in providing a plaster wall, concrete, concrete block and bricks, asbestos cement sheets, cement based renderings with one or two coats of snowcem washing or cement paint for protection and decoration. Cement paint consists of a base of white cement mixed with finely powdered colouring pigments to have the desired colour and with the addition of small quantities of other ingredients. It gives a water proof surface. It is sold by the manufacturer in 40 kg drums, 20 kg drums and 5 kg tin of various colour.

22.2 MATERIAL

High quality material from approved manufacturer as stated in the Schedule of works.

Before purchasing the material the contractor shall submit the list showing the brand, name and type of cement paint with country of origin which is proposed to be used in the work. Manufacturers, catalogue, specification sheet, expiry date of use shall be submitted to the Engineer for approval.

No material shall be used without the approval of the Engineer. All rejected materials shall be removed from site immediately.

All materials shall be of the best quality and be delivered to site in unopened original container bearing approved manufacturer's label.

Materials to be used shall conform to BSTI standards and reputed manufacturer's specification.

22.3 COLOUR AND SAMPLE

Before application of cement paint, samples shall be prepared as directed on a piece of same kind of surface upon which the same shall be applied. Colour and sample shall be varied until it is approved by the Engineer or Architect.

22.4 MIXING

Only fresh cement paint should be used. Hard or set cement paint should not be used. The contents should be made loose by rolling and shaking the container before opening the container. First a paste shall be prepared by mixing 2 parts of cement paint powder with one part of water to have a uniform solution of consistency of paints.

22.5 METHOD OF APPLICATION

The surfaces must be sound, clean, free from oil, greese, loose materials, organic growth etc. Cleaning should be done with soft brush. Spores of organic growth should be killed with blue circle fungicide. For old works the existing colour, if any, is to be rubbed off and the surface made smooth. The absorbent surface shall then be wetted with water or primed with cemprover diluted with equal measure of water or primed with blue circle stabilising solution. For maximum adhesion cement paint should be scrubbed into the facing. To reduce the risk of bloom apply in good

weather condition and not when there is risk of frost. The fresh mixed cement paint shall then be applied with broad good quality brush. The first coat shall be well brushed into the surface to form a good bond. Cement paint should be used within an hour of mixing and should be kept on stirring during application. Lid should be replaced and brush washed frequently. At the end of the day each application of cement paint surface should be wetted with fine water spray for curing.

After a day or two when the 1st coat is rock hard a second coat of cement paint of similar preparation should be applied on the wetted surface and the second coat should be applied carefully to give a uniform and good finished appearance. Brush mark, if any, must be obliterated and the surface textured by light stippling.

22.6 PRECAUTIONS

- 1) Cement paint is not recommended for external application for common bricks unless these bricks are dry. It should not be used on gypsum plaster, glass paints, distempers or emulsion paints.
- 2) In all cases the manufacturer's instructions shall be followed meticulously.
- 3) The lids of drums shall be kept tightly closed when not in use.
- 4) Don't allow next coat before the previous coat is dried up and cured.
- 5) Don't forget to water the surface.
- 6) After the final coat is given spray water over cement paint surface for curing for a minimum of 5 to 7 days.
- 7) Examine that it does not come out with finger tips when pressed over it.

TEXTURED PAINTING/BONTILE WORK

22.7 SCOPE

The work covered by this item consists in providing a paste like product having special aggregate to facilitate drawing desired textured patterns on the walls. The product is based on a special type copolymer/terpolymer which makes the product very tough and flexible. The pigments selected are highly weather resistant. It is washable. It can be applied on both exterior and interior walls, plaster, concrete, bricks or hardboard. It is available in different shades-cement grey, ceramic red, olive green, fresh orange, rose pompadour, white etc.

22.8 MATERIALS

Material shall be of same standard & specification as stated in Section 22.2

22.9 METHOD OF APPLICATION

The surfaces to be painted must be sound, clean, free from oil, grease, loose materials, organic growths etc. Repair surface defects before painting to have a smooth surface and free of voids or projections. The epoxy based textured coating in the ceiling or wall surfaces shall be applied with special type of nozzle or appropriate applicator. The first coat shall be a coat of normal sealer (N.Sealer) which prepares suitable base for the subsequent texture coat. Then the texture coat is sprayed uniformly with appropriate applicator/air pressure nozzle (Nozzle size is from 5mm to 8 mm) on the surface in three dimensional patterns to choice heavy — fine texture to a small area. Before it starts drying on the surface apply pattern roller when the paint is semi-dry condition to get the desired effect. Finally spray two coats of top coat of desired colour shade.

For smoother texture the B.P. compound may be sprayed after appropriate thinning with water/thinner specified by the manufacturer. Sometimes to get water repelling and glittering effect glazing liquid as per manufacturer's specification may finally be applied.

22.10 PRECAUTIONS

- 1) Do not apply on old paintings unless it is very hard.
- 2) Thinning is not normally required.
- 3) Do not keep the can open when not in use.
- 4) Unless there is deep hole which however be filled with appropriate filler/stopper, cracks or small holes or any imperfections of the wall will be covered by the thick film of the paint.

PATENT STONE FLOORING**23.1 SCOPE**

The work covered by this item consists of providing artificial patent stone flooring with cement concrete in the proportion of 1 part cement, 2 part sand (50% local sand of FM 1.2 and 50% Sylhet sand of FM 2.5) and four parts of clean, twice washed 12mm down graded picked jhama chips and finishing the top with neat cement.

23.2 MATERIALS

Cement : Ordinary Portland Cement Type-1

Sand : Sand shall be 50% local sand of FM 1.2 and 50% Sylhet sand of F. M. 2.5.

Coarse aggregate: Coarse Aggregate shall be 12mm (1/2") down graded picked jhama chips.

Samples of sand and coarse aggregate shall be approved by the Engineer-in-charge before use.

23.3 METHOD OF CONSTRUCTION

Before proceeding with the work a sample panel of flooring shall be prepared for approval by the Engineer-in-charge.

The sub-floor over which the artificial stone flooring will be laid shall be thoroughly picked and washed clean of laitance, dust, dirt and other foreign materials. Following the preparatory work, the sub-floor shall be thoroughly wetted with clean water by ponding at least overnight prior to the application of the flooring. All excess water shall be removed ahead of the application of the bonding slurry, so that the concrete surface is uniformly damp but not glistening wet.

A creamy bonding slurry of cement shall be applied and well scrubbed into the surface with stiff bristle brushes. Only as much bonding slurry shall be mixed and applied as will be covered by the succeeding coat before the slurry dries out. In general not over 10m² (100 sft) shall be slurried at one time in order to maintain a 'live glue' for bonding. Apply and brush in the slurry in small areas not exceeding 2.5 sq.m. Excess or dead slurry shall be constantly removed from the base by broom.

Before laying the concrete mix, temporary dividers shall be installed to pour concrete in 'chequered board' plan. The temporary dividers may be of metal strips or wooden battens of true line and shape. The top of the dividers shall be perfectly level with the level of the finished floor desired.

Concrete mix shall be applied promptly in specified thickness after slurring before the paste has hardened or dried. The method of measuring and mixing cement, sand and khoa shall be as per specification described elsewhere for cement concrete. The mixture shall be spread evenly between the battens. It shall be brought to an even grade by means of a strike board, then beaten and prodded with wooden pattas to thoroughly consolidate it until the mortar comes to the surface and smoothed off with a wood float so as to give a surface free from depressions or irregularities. If

any depression has to be filled a small quantity of the finer materials in the proportions specified may be used but this should be avoided as far as possible.

Minimum 1.5 mm thick, neat cement finishing shall be done using cement powder strained through fine cloth and paste of cement shall be rubbed in the surface with the help of small steel trowels working on the surface carefully and repeatedly using at least 4 passes over the entire area till the neat cement finish is very smooth, polished, plane and hard.

The sequence of filling in the panels shall be on "chequered board" plan. The casting of the complementary sets shall be done at least 48 hours after the first set is cast and dividers removed.

The top shall be moist, cured for at least 7 days by banding with a cement sand lean mortar band and not with mud. The flooring shall not be subjected to moderate use before 14 days and to severe use before 28 days.

23.4 COLOURED FLOORING

3mm thick coloured topping made of a mixer of 1 part of red oxide of iron or any other approved colouring materials and 3 to 6 parts of portland cement. For coloured cement floor, mix pigment colour with neat surface cement in the proportion of 1:3 to 1:6 (coloured : cement) to have the desired colour. White cement mixed with colour pigment to the desired proportion may also be used, but for strength it is better if ordinary portland cement is mixed with white cement in the proportion of 1:1 to 1:3 (grey portland cement: white cement) and then to add colour pigment to have the desired colour.

When colour pigment is mixed with white cement, the requirement of colour pigment is much less, may be 1:5 to 1:10 (pigment: white cement).

The proportion shall be decided after making several sample mixtures.

The mixture shall be mixed dry thoroughly by hand till a uniform mix is obtained. Then it should be screened through fine cloth so as to attain the best uniformity of the mix. Water shall be added gradually and the mixture turned over carefully so that a uniform paste is obtained. Water shall be used very sparingly, as otherwise, the colour will be spoiled by efflorescence.

The paste shall then be laid very carefully over the artificial stone flooring to a thickness of 3mm to obtain a smooth surface. A rectangular English trowel shall be used for finishing. The surface shall be tested with a straight edge and a spirit level. It shall then be left for twelve hours undisturbed so that it dries up slowly.

It shall then be polished with soft stone. Three different types of polishing stones one after the other shall be used till a perfectly smooth and glossy surface is obtained. While polishing the surface, sufficient water shall be used and all round off.

For coloured floor, if the floor dries up quickly, hair cracks shall develop. On the other hand, if water is kept stagnant for curing, floor shall be discoloured. So curing of coloured floor shall be done by hessian cloth or jute bag kept wet for several days.

23.5 PRECAUTIONS

Flooring must be done according to "chequered board" plan after every 48 hours of doing the earlier one.

No slope should be given in bed room, drawing room. Proper slope for natural drainage shall be given in kitchen, verandah, bath room etc.

Mud must not be used for preparation of band for curing the floor to avoid stain of mud on the floor.

For coloured flooring, mixing of colour should be done thoroughly and percentage of colour should be kept constant to give a uniform look.

Curing of coloured floor shall be done by wetting hessian cloth or jute bags instead of stagnant water to avoid discolouring of the floor.

Cement coloured patent stone flooring shall be done after about 10 to 12 days after the finishing work is completed.

CAST-IN-SITU TERRAZO FLOORING**24.1 SCOPE**

The work covered by this item consists of providing cast-in-situ finished terrazo flooring of required thickness specified in the schedule of items of work. The proportion of materials like marble chips, white and grey cement shall be as specified in the schedule of items of works.

24.2 MATERIALS

Grey cement shall be of Ordinary Portland cement type-1. White cement shall be of Japanese origin or as specified in the Schedule of work. Marble chips shall be of Indian or Pakistani origin as stated in the Schedule of items of work. 10mm down graded marble chips shall be of colour or colourless as approved by the Engineer-in-charge. The grading of marble chips shall, unless otherwise specified be in 2 parts 10mm and 1 part 6mm.

24.3 PREPARATION

The sub-floor on which the terrazo floor shall be laid shall be prepared as per section Artificial Patent Stone Flooring excepting the finishing top.

The marble chips shall be washed thoroughly in clean water taking small quantities in bamboo baskets and dip washing it in water drum or container. After washing properly dead and defective marble chips to be taken out and the chips should be properly dried before mixing with cement.

Sample terrazo work shall be approved by the Engineer-in-charge before full scale execution of the work started. The design of floor layout shall be as per plan and instruction of the Engineer-in-charge or the Architect.

White and grey cement in the proportion as specified in the Schedule of items of work shall be mixed dry thoroughly by hand until a uniform colour is obtained. After mixing white and grey cement, great care shall be taken to protect the mix from harmful effects of moisture. White and grey cement shall be mixed dry in such quantities which is sufficient for the whole area of one shade. The mixer of white and grey cement shall be mixed dry thoroughly by hand with marble chips in proportion as specified in the Schedule of items of work until a uniform colour and grading is obtained. For better result the mixing ratio of mixer of cement to marble chips may be 4:5 to 4:5.5

24.4 METHOD OF CONSTRUCTION

Following the preparatory work, a creamy bonding cement paste shall be applied and scrubbed into the surface of sub-floor with stiff bristle brushes.

Next the concrete setting bed of specified thickness and proportion shall be laid over the bonding paste and shall be compacted by wooden float to required level. Excess or dead slurry shall be constantly removed from the base by broom.

The floor shall be divided in panels for providing contraction joints. Unless otherwise specified, the area of a panel shall not exceed 1 sq.metre. The temporary dividers may be of metal strips or wooden battens where edges shall be perfectly level with the desired level of the floor finish. The sequence of casting shall be as 'Chequer-Board' plan. The complementary panels shall not be cast till the divider strips are removed and 48 hours elapsed since the casting of the adjoining panels.

The thickness of the terrazo topping shall be specified in the Schedule of work but it must not be less than 10mm.

Water shall be added to the already prepared dry mix of such quantities as may be consumed in less than 30 minutes, the quantity of water being the minimum required for workability. Mixing must be done on clean water tight platform.

The layer of cement and marble chips mixture shall be well trowelled into the surface of the setting bed with desired level and slope. The layer shall be well compacted and all voids shall be filled with further materials. Special care shall be taken so that no void remains on the edge of the divider strip, where the mixture shall be hard pressed.

The mixture of the marble chips and cement must be laid on the concrete setting bed, while it is sufficiently green so that the two bonds and hardens together and acts as one slab.

The surface shall then be hand trowelled to an even surface flush with the top of the strip. The floor shall be kept moist throughout these operations and when the operations are complete, it shall be cured for at least 7 days.

After the terrazo topping has hardened and cured for at least 7 days it shall be polished manually or with surface grinding machine. The grinding is to remove laitance or loose materials and to produce a smooth finishing.

The first grinding shall be done with a coarse carborundum stone (80 grit) to expose the marble chips.

Fine sand shall be sprinkled over the surface and water shall be used freely. All ground off materials shall be removed by sweeping and flushing with clean water after the first grinding is done.

All pores, holes, blemishes shall then be filled with a thin grout of white and grey cement mixture of same composition. On hardening of patch filler at least after 5 days the second grinding shall be done using carborundum stone of 120 grit. The surface shall then be cleaned twice using clean water and light grout of white and grey cement mixture of same composition shall be spread over the entire floor and be allowed to fill in all fine voids. After the grout has hardened for 3 days the surface shall be subjected to final grinding with carborundum stone (210 grit). The floor shall be washed thoroughly after each grinding and in the final grinding washing shall be done with hot water and pure soft soap.

After washing, cleaning and drying the floor, oxalic acid shall be dusted over the surface (2-3 lbs per 10 sq.m). The floor shall then be sprinkled with water and rubbed hard. This operation shall be repeated till the surface has acquired the required glaze. The following day, the floor shall be wiped with a moist rug and dried with soft cloth.

A hot mixture of tarpentine and bee-wax (2:1) shall then be applied to the surface and thoroughly rubbed in with hand and again rubbed with clean cotton waste using 4 passes. The rubbing shall be continued till the floor ceases to be sticky. Best result can be obtained with a minimum of wax and maximum of rubbing.

The item is inclusive of the preparation of minimum 25mm thick patent stone flooring.

24.5 CAST-IN-SITU TERRAZO FLOOR WITH GLASS DIVIDER

In case of terrazo floor with glass dividers, 5mm thick and 20mm deep glass dividers shall be used in panel joints as per design and direction of Engineer-in-charge.

The glass dividers shall be placed so that the top edge shall be perfectly levelled with the top level of the desired floor finish.

Special care shall be taken in case of terrazo floor with glass dividers while pouring mixture of marble chips and cement so that no void remains on the sides of the dividers. The mixture shall be pressed hard on the face of the glass divider.

24.6 CAST-IN-SITU TERRAZO WALL AND SKIRTING

Composition and materials for cast-in-situ terrazo wall and skirting shall be same as specified for situ terrazo flooring in section 24.2.

The thickness of terrazo topping shall be minimum 10mm (3/8").

The wall on which the situ mosaic would be applied shall have to be cured for 6 hours. The surface shall be scrubbed with steel brush using clean water generously and the surface shall be brought to a spark-clean condition. In case of brick work, the mortar joints shall be raked at least 10mm(3/8") deep. The wall shall be saturated with water and kept moist continuously for 8 hours before the work is to begin.

Instead of 25mm (1") patent stone setting bed, 10mm (3/8") thick cement plaster (1 : 4) shall be used as setting bed. If the thickness of setting bed exceeds 12mm (1/2"), it shall be applied in multiple layers, each layer not more than 12mm (1/2"). In case of multiple layers, the previous layer shall be treated as a scratch layer and the surface shall be left sufficiently rough for good bonding with the next layer. Subsequent layer shall not be applied before the previous layer has hardened. The previous coat shall be treated with thick slurry of cement before the application of successor layer.

In any case, the final layer shall be left sufficiently rough for good adherence of the topping.

The setting bed shall be applied in such a way that, it provides a true surface and plumb which will be scratched with broom and allowed to cure for at least 24 hours.

Next a coat of bonding paste of neat cement (Portland cement) shall be trowelled on the setting. The setting bed shall be moistured before application of bonding slurry in such a way that it is damp only and not glistening wet.

The terrazo topping layer shall then be well trowelled in 10mm (3/8") thickness over the line bonding paste. The ingredients of terrazo topping layer shall be mixed in proportion and in manner as specified for situ terrazo flooring and approved by Engineer-in-charge.

On hardening enough to withstand dislodgement, the terrazo surface be finished in similar way as specified for situ terrazo flooring, exception that the work shall be done manually.

TERRAZO TILE FLOORING**25.1 SCOPE**

The work covered by this item consists of providing terrazo flooring with tiles of size as special in the Schedule of items of work.

25.2 MATERIALS

Materials shall be same as specified for cast-in-situ terrazo flooring. Thickness of finished terrazo topping shall be minimum 10mm. The thickness of cement mortar base over which the topping shall be machine pressed shall be minimum 12mm with a proportion of 1:2.

25.3 METHOD OF CONSTRUCTION

The tiles shall be machine moulded, uniform in colour with minimum 10mm terrazo top and minimum 12mm setting base pressed together in the machine. The tiles shall be cured for at least 7 days.

Before mass scale production, sample tile shall be approved by the Engineer-in-charge.

The design of floor layout and colours shall be as per plan and instruction of the Engineer-in-charge or the Architect.

The tiles shall be laid on 40mm thick cement slurry and hydraulic lime and surki in proportion of 1:3 with proper slope or as specified in the schedule of item. No divider strip shall be used. The joints shall be painted with white cement.

The tiles shall be grinded, polished and washed as per terrazo-in-situ work after setting the tiles in position.

Also cement motor (1:4) may be used in place lime mortar and the process may be followed as cited.

GLAZED TILE WORK**26.1 SCOPE**

The work covered by this item consists of providing glazed tiles on walls and floors.

26.2 MATERIALS

Glazed tiles if specified as local shall be manufactured by BISF and foreign made glazed tiles shall be from the country as specified by the Engineer-in-charge. Setting bed for wall shall be cement mortar with proportion 1:3 and for floor 1:2. Colour and size of glazed tile shall be as specified by the Engineer-in-charge or the Architect.

26.3 METHOD OF CONSTRUCTION

For walls, the top of the glazed tiles shall be in the same line with full tile at the top. No cut piece tile shall be laid at the top. For maintaining level in the bathroom, a slope is provided towards outlet of water, as such bottom lines of the four walls shall be at different levels. First a line shall be drawn on the four walls of the bathroom in such a way that the height of the wall upto which tiles shall be laid shall be a multiple of the height of the selected tile, so that no cut piece tile is required to be laid above this selected bottom line. Area below the selected line shall be fitted up by cut piece tiles of different heights according to the slope of the floor. It must be remembered that floor tiles shall be laid only after completion of wall tile work. If the floor is made of terrazzo tiles, area below the bottom selected line may be made of cast-in-situ terrazzo wall.

Glazed tiles shall be laid true to levels and in plumb line. The tiles shall be press laid in such a way that no hollow space remains between the tiles and the base mortar.

If there is a false ceiling in the bath room and the wall tiles are laid upto the bottom of the false ceiling, then the ceiling plaster of the false ceiling shall be done after laying the wall tiles to maintain perfect horizontal line between the junction of top level of the tiles and the plastered bottom of the false ceiling.

The joints of the tiles shall be filled with white cement to arrive at an uniform and smooth joints.

The tiles shall be cured at least 7 days.

Floor tiles shall be non-slip or as specified in the Schedule of items of work and as directed by the Engineer-in-charge.

Floor tiles shall be laid by maintaining proper slope towards drain on cement mortar bed of 1:2 proportion. Proper care shall be taken so that no hollow space remains in the mortar bed.

The joints shall be filled in with white cement.

REPAIR METHODOLOGY BY FERRO-CEMENT LAYERS**27.1 MATERIALS**

1. **Cement:** Cement shall be Ordinary Portland Cement Type 1 conforming to BDS 232-1974.
2. **Sand:** Sand shall be clean, hard, strong, free from organic matters, impurities and deleterious substances. Sand shall be cleaned by water before use. Fineness Modulus of sand shall be minimum 2 and all sand shall pass through standard sieve no. 8.
3. **Coarse aggregate:** Coarse aggregate for micro-concrete shall be crushed stone 5mm (3/16 inch) down graded.
4. **Water:** Water used in the mix shall be potable water, free from organic and harmful solutions which lead to deterioration of the properties of mortar. In no case saline water shall be used.
5. **Reinforcing mesh:** The most essential component of ferro-cement is steel wire mesh. Many types are available in the market but the main essential requirement is that it must be easily handled and flexible enough to be bent around sharp corners.

The specifications of wire mesh are as follows :

Diameter of wires : 18 to 20 gauge

Mesh size : 8 x 8mm to 12 x 12mm

27.2 REPAIR METHODOLOGY

Repair of concrete slab by application of ferro-cement layers consists of:

- a) Choosing proper materials
 - b) Preparation of affected surfaces
 - c) Providing bonding layer
 - d) Application of micro-concrete
 - e) Application of ferro-cement layer
 - f) Finishing the surface and curing
- a) **Choosing proper materials :** Standard of materials and their quality has been discussed under section 27.1
 - b) **Preparation of affected surface:** Prior to execution of repair work of affected surfaces, the most essential requirements is to remove all deteriorated or damaged concrete from the slab. The affected slab shall be thoroughly scrubbed and cleaned from all greases, dirt or grit, roughened by chiseling or wire brush, washed with water and air blown to remove any loose materials.

If only cracks are to be repaired these shall be widened to form a dove-tailed groove commonly known as chases. The sides of the chases shall be sloped 1:2. The surfaces of the chases must be free from dirt, dust and loose particles.

In preparing surfaces of the slab, all unsound, damaged, fouled, porous or otherwise undesirable concrete shall be removed. Where it is not obvious that the sound concrete has been reached, the common rule of thumb is that a concrete which is difficult to remove is good concrete.

Reinforcing bars in the spalling areas shall be exposed completely at least 20mm all around so that these can be fully encased in a new micro-concrete.

The surface of the existing concrete which is to be bonded to new work shall be cleaned and moistened just prior to placement of new concrete.

After cleaning, the surface shall be saturated with water and then allowed to approach dryness just before placing the bonding medium. The surface shall be kept moistened for several hours to assure saturation.

The exposed reinforcement shall be cleaned of all corrosion, oil, dirt and similar foreign materials. Both air blowing and wire brushing shall be used for cleaning the bars.

- c) Bonding layer: To ensure sufficient bond between old and fresh ferro-cement layer, a bonding layer shall be provided. It shall consist of cement slurry with 1 part by weight of cement and 0.5 part by weight of water. Cement slurry shall be applied on the exposed surfaces.
- d) Micro-concrete: The deteriorated concrete surfaces thus prepared are now ready for application of micro-concrete and ferro-cement layer.

The exposed surfaces of the reinforcement towards the core section shall be filled with micro-concrete with a mix ratio of 1:1:2 by volume to rebuild the slab section upto the reinforcement. The coarse aggregate for micro-concrete shall be crushed stone 3/16 inch down graded.

Micro-concrete shall be allowed to set before the mesh is hanged for ferro-cement layer.

- e) Ferro-cement layer: 6mm dia wire nails at 500mm centres shall be pushed into the micro-concrete. The chosen wire mesh shall then be hanged by tying the wire mesh with 24 gauge G.I. binding wire loops to the nails. The nails shall be projected out to support the next mesh. 8-10 mm cement-sand mortar matrix with a ratio of 1:2 by volume shall be laid by hand trowel over the micro-concrete. The matrix shall be allowed to set for about 12 hours.

After the application of first layer, another wire mesh shall be hanged in the same manner as stated earlier. Another mortar layer of 8-10mm thick shall be laid over the first layer after about 12 hours. Before the application of second layer the surface of the first layer shall be roughened for proper bondage.

- e) Surface finishing: The surface shall then be levelled to the desired level and the repaired areas shall be cured for 10 days with clean water. Under no circumstances saline water shall be used for curing.

27.3 REPAIR OF WIDER CRACKS

For repair of wider cracks in the slab, stitching of cracks shall be done by randomly oriented 6mm dia. stitching dogs before the application of Ferro-cement. These stitching dogs shall be on variable length and/or orientation, so that the tension transmitted across the crack does not develop on a single plane of section. Stitching dogs shall be fixed to the existing concrete by drilling holes and filling the holes with cement grout.

27.4 REHABILITATION OF DISTRESSED BEAM

For the rehabilitation of distressed beam, a length equal to twice the depth of the beam may be considered at a time and the two vertical sides as well as bottom of the beam may be encased by ferro-cement continuously at a time. The materials used for rehabilitation and the procedure used for repair works shall be similar to that of slab. The spacing of nails and their projection above the

surface for fixing wire mesh shall be about 200-250mm and 25-30mm respectively. In case of greater depth for repair work, small lengths of additional skeleton steel bars 6mm diameter shall be tied by galvanized wires transverse to the longitudinal reinforcement of the beam.

The procedure of placing ferro cement is stated below :

1. The exposed sides of the reinforcement towards the core section of the beam shall be filled with micro-concrete with a mix ratio of 1:1:2 by volume to rebuild the beam section upto the stirrups.
2. The first wire mesh shall be laid around the beam allowing the micro concrete to set 24 hours. After fixing the wire mesh with galvanized wire to the nails, the mesh shall be covered with 8-10mm thick cement-sand mortar with a ratio of 1:2 by volume.
3. After about 12 hours of the mortar application, the surface shall be roughened again and the second layer of wire mesh shall be placed over the area and fixed as before. The mesh shall then be covered again with 8-10mm thick mortar.
4. The same procedure shall be repeated for the third time, if needed, to rebuild the initial cross section of the beam. The thickness of the third layer may be upto 12mm.
5. The surface shall be finished upto the desired level as per usual practice.
6. Curing shall be done by covering the rehabilitated area with Hessian and keeping it constantly wet for about 14 days.

27.5 PRECAUTION

Before rehabilitation work is started the slab on both sides of the beam shall be properly propped up to receive the slab load.

27.6 REHABILITATION OF DISTRESSED COLUMN

Preparation of distressed surface of column is similar to that of slab and beam. In case of greater depth of repairing work skeleton steel shall be provided in the form of ties and fixed with projected nails and main bars of the column with G.I. wire.

The procedure of placing the ferro-cement is stated below:

1. The exposed sides of the main reinforcement towards the core of the column section shall be filled with micro concrete to rebuild the column section upto the ties.
2. The first wire mesh shall be laid all around the column section or part of the column to be repaired after about 24 hours of placing the micro-concrete for allowing it to set. After fixing the wire mesh to the nail the mesh shall be covered with 8-10mm thick sand cement mortar of proportion 1:2 by volume.
3. After about 12 hours of first application, the surface shall be roughened, the second layer of wire mesh shall be laid and covered with 8-10mm thick mortar as in step 2.
4. The same procedure as in step 3 shall be repeated for the third time, if needed, applying 10-12mm thick mortar matrix to rebuild the initial section of the column.
5. The surface shall be finished to the desired level as per normal procedure.
6. Curing shall be done by covering the rehabilitated area with Hessian and keeping it constantly wet for about 14 days.

PRECAUTION

Beams resting on the distressed column shall be properly propped before rehabilitation work of the column is started.

CORRUGATED IRON ROOFING AND FALSE CEILING

28.1 SCOPE

The work covered by this item consists in providing C.I. sheet roofs over timber or steel trusses. Due to its vulnerability to storm and cyclone, it should be used sparingly, in semi-permanent construction and where it should be erected true to line and level and should be adequately fixed/secured to prevent movement or damages.

28.2 METHOD OF CONSTRUCTION

Corrugated galvanised 0.45 mm thick Iron sheets should be used for roof coverings. The laps in the sheets will be 150 mm lengthwise and one full and two half corrugations on the sides. In the ridges and the hips where plain sheets are used the width of the laps shall be 225 mm.

The sheets shall be fixed to the purlins with galvanised screws properly threaded not below 45 mm long. In no case these should be hammered as hammering makes depression on the C.I. sheet and causes leakages. The purlins secured with twisted clamps and rose nails of sufficient length to project out of the purlins and bent alternative to the rafters. The rafters are again fixed to the wall plate with 12 mm dia bolts and nuts. The wall plates all along the length of the wall shall be fixed with holding down bolts 16 mm dia sufficiently long to be anchored with the casting of the lintel, preferably the rafter, wall plate be joined with the same holding down bolt as a prevention against its blowing away by storm.

In case of iron trusses the sheets are all to be fitted with 6 mm dia hook both with sizes befitting the truss members to which it will be fitted. Earth oiling, painting etc. should be applied to all wooden members before fixing in position.

Holes in the C.I. sheets should be made from inside for guarding against leakage. It should be on the top most point on the ridge. There should be two screws in the purlin line for each sheet. In the side joints there should be additional sheeting bolts in between the screws. There should also be sheet bolts at the joining point of two or more sheets in the corners. There must be limpet washers at the head of the screws to be fitted with putty.

There should be wind ties made of 38 mm x 6 mm flat bars secured on the top of the roof near the edge with 12 mm dia galvanised J-hook secured with the purlins and rafters.

28.3 HARD BOARD/PARTICLE BOARD/GYPSUM BOARD FALSE CEILING WORK

This item is suitable for providing less costly decorative false ceiling of a semi-permanent structure situated in a damp, dirt place where paint finishing fades easily with growing of fungus.

Method of Erection

Usually for false ceiling hard board or vinyl boards are available by sizes 8'-0"x4'-0". This is economical. It is needed to fabricate timber frame or steel frame of required dimension for fixing boards on it. Boards on frame can be satisfactorily fixed by nailing or screwing. Nails or screws are usually fixed to 8" c/c. After fixing the board to frame edges of panel should be covered with wooden bits, aluminum sections or steel sections. This grid or panel thus formed is suspended from ceiling or roof or beam by 12 B.W.G. double ply G.I. wires fixed to the ceiling by rowel plug, screws, hooks, nails etc. maintaining straight lines, levels etc. The desired finished level at bottom face with vertical strut as required should be maintained strictly.

28.4 PRECAUTIONS

- i) Holes in C.I. sheets should be made from inside avoiding hammering of the screws in the purlin.
- 2) Limpet washers at the head of the screws must be fitted and filled completely with putty.
- 3) Joint bolts should be adequately provided.
- 4) Ridges should be made straight and to the sizes, and adequately secured with joining bolts.

STEEL TRUSS WORK

29.1 SCOPE

Steel truss is used in the following construction

- a) Bridges - For rail roads, highways and pedestrian bridges.
- b) Buildings - including rigid frames, simple connected frames, load bearing wall, cable-stayed and cantilevered.

Numerous lateral bracing schemes including trussed, staggered trussed, and rigid central core may be used.

Other structures : power transmission towers, towers for radar & T.V. installations, telephone relay towers, water supply facilities and transportation terminal facilities, including rail roads, trucking, aviation and marine.

29.2 METHOD OF CONSTRUCTION

A truss is a formed structure composed generally of straight members so arranged and fastened together at their ends. The stresses in the members, due to the forces at the joints are either tension or compression. Most of the trusses in practice are composed of a number of triangles formed together.

The plane truss consists of a number of bars jointed together such that they lie in one plane & form a frame-work which is suitable against any type of loading acting in the same plane. The plane truss can be classified as

- a) Simple truss (b) Compound truss (c) Complex truss.

The simplest form of the truss frame work which should be stable can be formed as follows:

- 1) By connection three bars by means of pins to form a triangle in suitably connected to the foundations. This will form a rigid frame which will not collapse.
- 2) By taking two bars from rigid foundations and joining them by means of a pin at the end to form a triangle. This will form a rigid frame which will not collapse.
- 3) In any other form the frame work will not be rigid. For example the frame work consisting of four bars in the form of pollygon is not stable and can collapse as shown by dotted line.

Mild steel work in roof trusses, bridges, buildings and other structures should be done with mild steel sections of different sizes as per design and drawings. These sections are to be fitted and fixed in positions carefully as per design and drawing with gusset plates, nuts & bolts, rivets or by welding. Then after cleaning the surface adequately two coats of anticorrosive paint over a prime coat of red oxide or red lead shall be applied with appropriate applicator. To determine the number of rivets, we must know the design load, thickness of gusset plate and angles, the sizes of rivets and allowable unit stresses.

DOORS AND WINDOWS**30.1 SCOPE**

Doors and windows are frame-work of timber, steel, aluminium, metal, glass or combination of these materials. The main function of doors is to serve as a connecting link between various internal parts of the building unit and provides access to the users. Windows are provided to give both light and ventilation or to provide light only to the interior parts of the building. When the windows are provided for light and ventilation, some or all the portions of windows are designed with provisions of opening or closing. When for light only they may be fixed and known as fan light.

Doors and windows are provided with frames. Wooden or steel shutters are secured to the frames with the help of hinges. Attachments are also fixed to shutters enabling them to be closed for security or privacy point of view.

The size, number and location of doors and windows depend on room size, its use, light distribution, privacy, decoration of the room and will be provided as per architectural plan or as per requirement.

Types of doors

The most common types of doors in building construction are as follows :

1. Panelled doors
2. Glazed doors
3. Flush doors
4. Louvered doors/Glass Louvre
5. Sliding doors
6. Swing doors
7. Collapsible doors
8. Revolving doors
9. Rolling steel doors
10. Photo-sensing automatic doors.

Types of windows

The most common types of windows are as follows

1. Ordinary windows
2. Glazed windows, Steel/wood/aluminium

3. Louvered windows
4. Pivoted windows/Swing windows
5. Sliding windows
6. Metal windows
7. Fixed windows/Skylights
8. Top hung/casement window

30.2 MATERIALS

Usual materials for doors and windows are wood/timber, plywood, particle board, steel, aluminium, glass or combination of these materials. Wood is the most common material for doors and windows as it can be moulded into variety of shapes to present a pleasing appearance. The timber shall be Teak, Sal, Kathai, or any other wood as specified, well seasoned, dry, straight grained, free from large or loose knots, sap & shakes and will be finished to the exact dimensions shown in the drawings. Plywood can be used as a covering material. Glass is used for panels to admit more light. Metals, such as aluminium & steel are now being increasingly used.

Aluminium is a non-ferrous metal and is strong, durable and elegant in appearance. Aluminium doors & windows are used in high class buildings as these are rust proof, light in weight, free from corrosion, suffers from no colour fade and need no maintenance and painting. They may be of sliding, swing, fixed or casement type. Bangladesh Thai Aluminium (BTA) extruded and anodized aluminium profiles/sections and imported NIKKEI THAI sections of different sizes are available in the market. All aluminium sections are anodized in bronze or silver colour. BTA also fabricates numerous aluminium products including doors, windows, curtain glazing partition, grill etc. and allied products.

30.3 METHOD OF CONSTRUCTION

30.3.1 Wood work

The door and window frames shall be properly made and joined with mortice and tenon joint. They shall be rebated on one side 12 mm to 19 mm deep to the full thickness of the shutter in the other. For double doors or windows rebates shall be provided on both sides. The edges must be strictly in straight lines and the corner at perfect right angles.

The wood work shall be well planed, dressed, framed and fixed in position in consideration of opening of the shutter whether it will flush with the wall or at right angles and not necessarily in the centreline of the wall.

The surface of the frame in contact with the masonry or R.C.C shall be painted with coaltar or good quality paint. The frames shall then be fitted vertically in position in the opening true to plumb and fixed with m.s. clamp size 33 mm x 6 mm x 375 mm set in C.C. (1:2:4) within masonry of R.C.C. 3 in each vertical of door and 2 in each vertical of window.

The clamp shall be fixed to the frame by not less than 3 Nos. of 6 mm long screws.

The shutters may be of panelled, battened, flushed, louvered, venetian, glazed or as directed. They shall be made of best seasoned wood as specified. The styles, rails, panels etc. of the shutter shall be accurately cut or moulded and fitted to the dimensions shown in the drawings, and the joints will be put together with glue and/or screws as necessary. The panels shall be raised, flushed feather-tongued into the styles and rails with square corners and edges on both sides. The doors and windows may be of one, two or three or more leaves as specified and to be provided with cleats on hinges or other method specified for keeping the shutter open and also buffer blocks to prevent beating or dasting against the jambs.

Specimen of doors and windows with all fittings have to be made and got approved by the Engineer-in-charge before fitting and fixing at site.

30.3.2 Steel work

All steel shapes used shall be product of reputable manufacturer and shall conform to the BSI specifications. The sections, sizes and profile shall be true to size and shape as per requirement for the specific works as shown in the design and drawings. Joints shall be done with nuts and bolts, rivets or by welding. Locks, handles, hinges, bolts and other iron or brass fittings shall be provided as per drawing and direction of the Engineer-in-charge. The finishing and fittings shall be such as that the shutters can be operated smoothly and without strain.

Precautions

- 1) The members of the frame and sash should be properly welded.
- 2) The door & window units should be carefully stacked at site and carried while placing in position.
- 3) Checked slightly adjust the movement of shutters before erecting the same in the opening.
- 4) The masonry openings to receive the metal doors/windows should be made true to levels and plumb.
- 5) Glass panel should be properly fixed.
- 6) The handles to the windows should be fixed before doing the glazing work.
- 7) Scaffolding members or any other support should not be tied down to the metal doors or windows.
- 8) It is advisable to get a coating of suitable paint to the frames before transportation.

30.3.3 Aluminium Works

All aluminium sections shall conform to U. S. Architectural Aluminium Manufacturer's Association (AAMA) & BNBC 93 standard.

Extruded aluminium sections of various sections and sizes are available in the market. Specialized fabricators from the suppliers normally come to the site to fix the doors and windows according to the openings proposed by the architect. Sections of standard lengths are manufactured in the factory and it is cut to sizes according to the need of the owner.

When aluminium channels/sections are brought to site, it is the responsibility of the S.D.E./Sectional officer to check whether the thickness and size of the channel for different parts of the doors/windows conform to the specification as provided in the tender schedule as per Schedule of Rates of PWD. It must be kept in mind that different types of doors and windows, and different parts of the doors and windows may have different sections and thicknesses. For example, wall frame may have different size and thickness than the shutter frame. Site engineer should compare the size and thickness of different parts of the doors and windows with those provided in the Schedule of Rates and drawings as provided in the Analysis of Rates.

Site engineer shall keep in mind that there is wide scope of manipulation in the thickness & sections of aluminium doors and windows and many undersized sections are available in the market.

Proper care shall be taken so that doors & windows are made water tight by providing specified neoprene gasket

The doors & windows should be properly fixed to walls by screw and plastic plugs and the plastered surface should be true to plumb, so that no gap is formed after the sections are fixed to walls.

Glass thickness shall be minimum 5mm. While fixing the glass, neoprene and sealant should be used to make it water tight.

DEEP TUBEWELL**31.1 GENERAL DESCRIPTION**

Deep tube wells are defined as the wells normally deeper than 250 feet and drilled by direct or reverse circulation method to a large diameter with gravel pack around the screen, having housing pipe of sufficient length and diameter to accommodate a line shaft turbine or submersible pump.

The production well should be designed on the basis of the findings of the test tubewell unless otherwise specified. The well may be fitted with either a line shaft turbine pump, electrically or diesel driven, an electric submersible pump or a surface mounted centrifugal pump.

The essential requirements of a successful well are, first, that water may be procured in sufficient quantity within a convenient distance from the place of consumption and secondly, that the quality of water shall be sufficiently good for the intended purpose. Since PWD is generally concerned with water for domestic uses and human consumption the intended water should be free from turbidity and should be colourless, odourless and tasteless. Harmful micro organism and radioactivity must be absent or in other words it should be of the quality recommended by the World Health Organisation (WHO).

31.2 Selection of Wells

Selection of a deep tubewell depends on the quantity of water requirements and also on the condition of soil strata and ground water. Cost and technical factors must be properly analysed. It is not good engineering to design a well for a yield of 300 gpm to serve a suburban home when 15 gpm may fully satisfy the owner's need. In determining the maximum capacity of a well, the following formula may be used :

$$Q = 0.31A,$$

Where Q = Quantity of water in gallon per minute

A = Opening area of strainer in square inch.

31.2.1 Water Requirement for Domestic Use

Water requirements for daily domestic use of a building shall be assessed on the basis of the one or a combination of the following two methods:

- a) Number of occupants according to their occupancy classification and their water requirements as specified in Table 8.6.1. of Bangladesh National Building Code. (see table - I)
- b) Peak demand or maximum probable flow specified in Sec. P3 and P4 in the Appendix P of Bangladesh National Building Code.

Table - 1

Guideline for Water Requirements for Various Occupancies and Facility Groups in Litres Per Capita Per Day (LPCD)

Class of Occupancy	Occupancy Groups	For Fulla Facilities (LPCD)	For Restricted Facilities (LPCD)
Occupancy A: Residential	A1: Single Family Dwelling	400	135
	A2: Flats or Apartments	225	135
	A3: Mess, Hostels, or Boarding House	135	70
	A4: Minimum Standard Housing	-	70
	A5: Hotels or Lodging House (Per bed)	300	135
Occupancy B: Educational	B1: Educational Facilities	70	45
	B2: Preschool Facilities	50	35
Occupancy C: Institutional	C1: Institution for Children's Care	180	100
	C2: Custodian Institution for Capable	180	100
	C3: Custodian Institution for Incapable	120	70
	C4: Penal and Mental Institution	120	70
Occupancy D: Health Care	D1: Normal Medical Facilities	450	225
	D2: Emergency Medical Facilities	300	135
Occupancy E: Assembly	E1: Large Assembly with Fixed Seats(per seat)	90	45
	E2: Small Assembly with Fixed Seats(per seat)	90	45
	E3: Large Assembly without Fixed Seats ^b	8	5
	E4: Small Assembly without Fixed Seats	8	5
	E5: Sports Facilities	8	5
Occupancy F: Business and Mercantile	F1: Offices	45	30
	F2: Small Shops and Markets	45	30
	F3: Large Shops and Markets	45	30
	F4: Garage and Petrol Stations	70	45
	F5: Essential Services	70	45
Occupancy G: Industrial	G1: Low Hazard Industries	40	25
	G2: Moderate Hazards Industries	40	25
Occupancy H: Storage	H1: Low Fire Risk Storage	10	6
	H2: Moderate Fire Risk Storage	10	6
Occupancy J: Hazardous	J1: Explosive Hazard Building	8	5
	J2: Chemical Hazard Building	8	5
Occupancy K: Miscellaneous	K1: Private Garage & Special Structure	8	5
	K2: Fences, Tanks and Towers	-	3

a For full facility in occupancy classifications A, B, C and D, the water requirement value includes 25% hot water.

b In the case of mosques, the water requirements given above shall be adequate for ablution and other uses of one devotee per prayer. The appropriate LPCD value may be calculated on this basis.

c Water requirement for occupancy K is shown as a provision for unknown visitors only.

31.3 METHOD OF CONSTRUCTION

31.3.1 Test/observation well

a) Well site

The well shall be constructed at the location indicated by the Engineer-in-charge, which shall normally conform to the following conditions :

- The location of the tube well shall be sufficiently away from any probable source of contamination
- The location of the tube well shall not be susceptible to normal flooding or any other damage.
- The location of the tube well shall allow for convenient construction of a platform with facilities for drainage.

b) Well Drilling :

In sinking the test/observation well, the contractor shall generally use the most common and indigenous method of well drilling i.e. the water jet system of drilling. But depending on the geological condition of the formation any other suitable method may also be employed.

Drilling shall be done for a bore hole of 100mm dia by the contractor with his own drilling tools. Boring shall be carried out upto the required depth as per instruction of the Engineer-in-charge through all kinds of soils such as consolidated or unconsolidated formations. Casing pipe shall be used during boring where necessary at contractor's own cost. No fluid like crowdung shall be used in the drilling which may contaminate the water in the well.

The contractor shall maintain the daily progress of boring and submit progress reports to the Engineer-in-charge describing depth of boring with log, hardness and colour of the Strata etc.

c) Collection of Soil Samples :

The representative soil samples shall be collected at every 3m of boring and at every change of formation. Before taking samples, washing of bore hole shall continue for at least 30 minutes to get a proper representation of the formation.

Each sample shall be divided into two parts, 500 gm each. One part shall be kept for grain size analysis and shall be put in a polythene bag, tightly closed and properly labelled indicating the depth from which the sample has been taken. The second part shall be kept at site in a specially made honey combed wooden box for inspection by the Engineer. When drilling is completed upto the required depth, samples preserved in the polythene bags shall be sent at contractor's own cost to the Laboratory of BUET, Dhaka for necessary tests as per contract. Cost for soil sampling and transportation of samples are included in the contracted rates.

d) Depth of Well :

Success of the well is the responsibility of contractor. He shall install the screen at the most suitable strata within the specified depth. If no good layer is encountered within the specified depth, the contractor can decide in close consultation with the Engineer-in-charge, to drill beyond this depth.

If a good water bearing strata is encountered above the specified or actually drilled depth the Engineer may propose to the contractor to install the screen there. The contractor will not claim any enhanced rate for this and will be paid for the depth he actually drilled and for the length of actually installed well features at the contracted rates.

3) Well Design :

Test/observation well shall be constructed in accordance with the design of the Engineer-in-charge shown in Figure 31.1, 31.2 and 31.3 generally with the following components : -

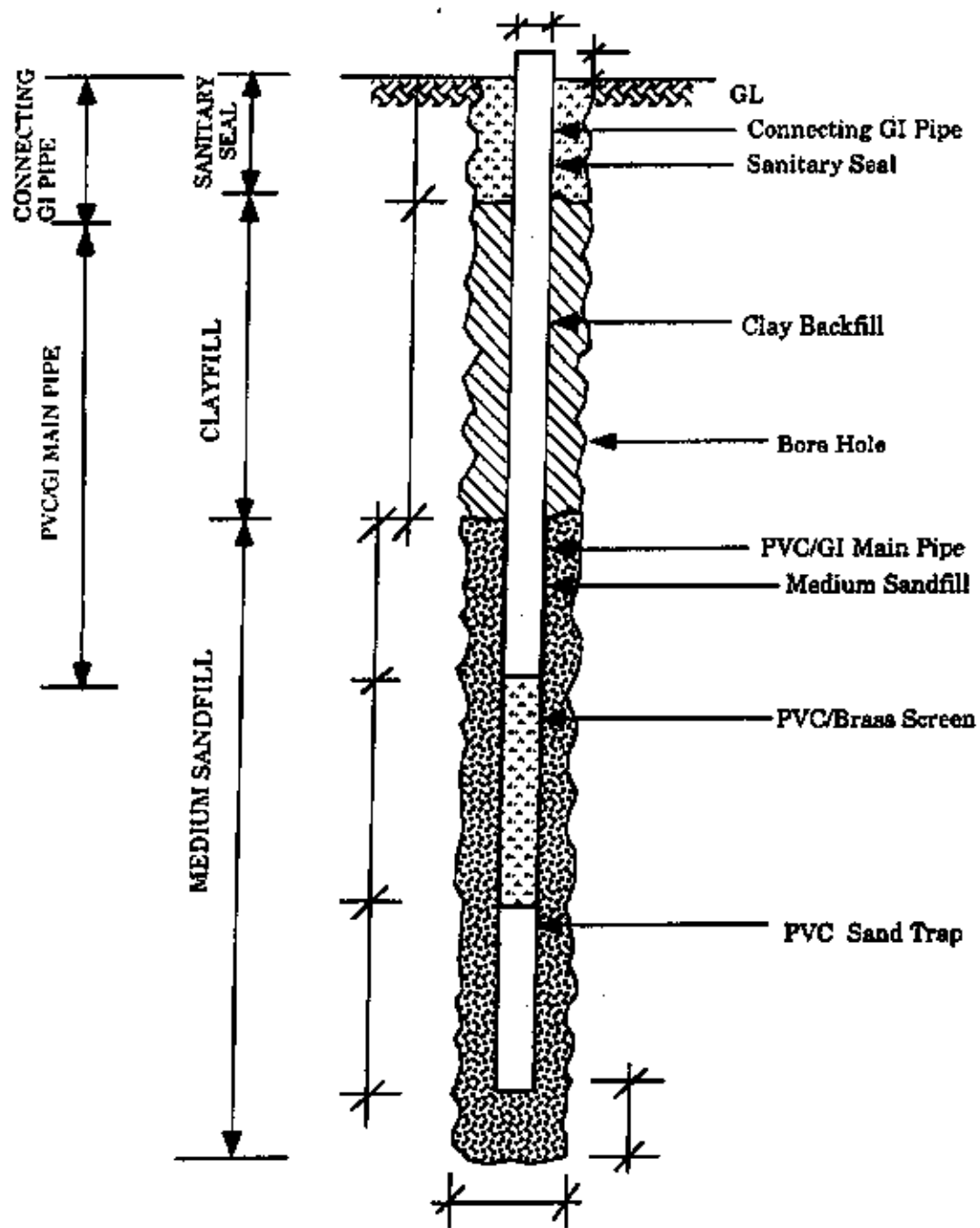
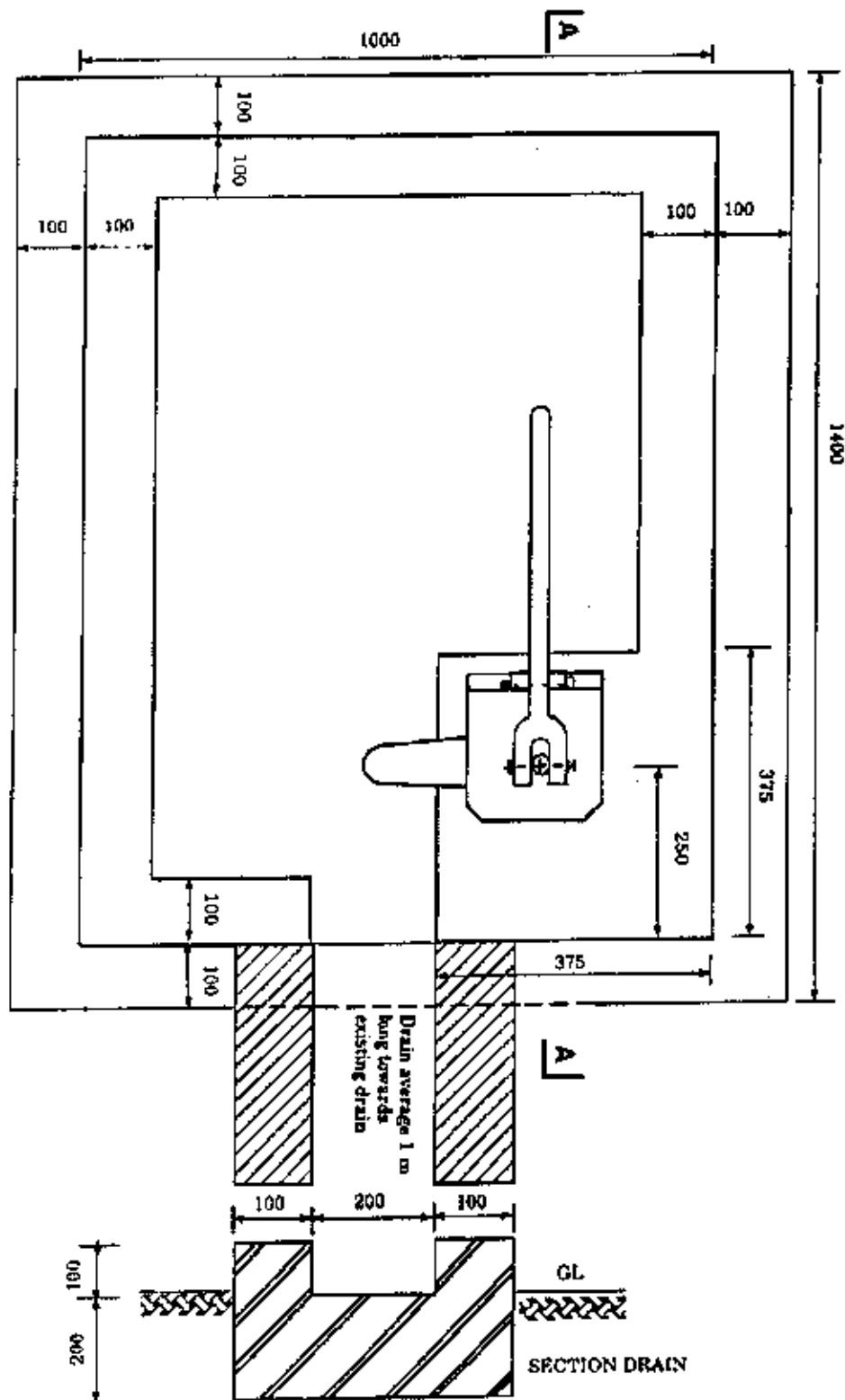


FIG. 31.1 TYPICAL CROSS SECTION OF A TEST/OBSERVATION WELL

FIG. 31.2 PLATFORM FOR HANDPUMP TUBEWELL



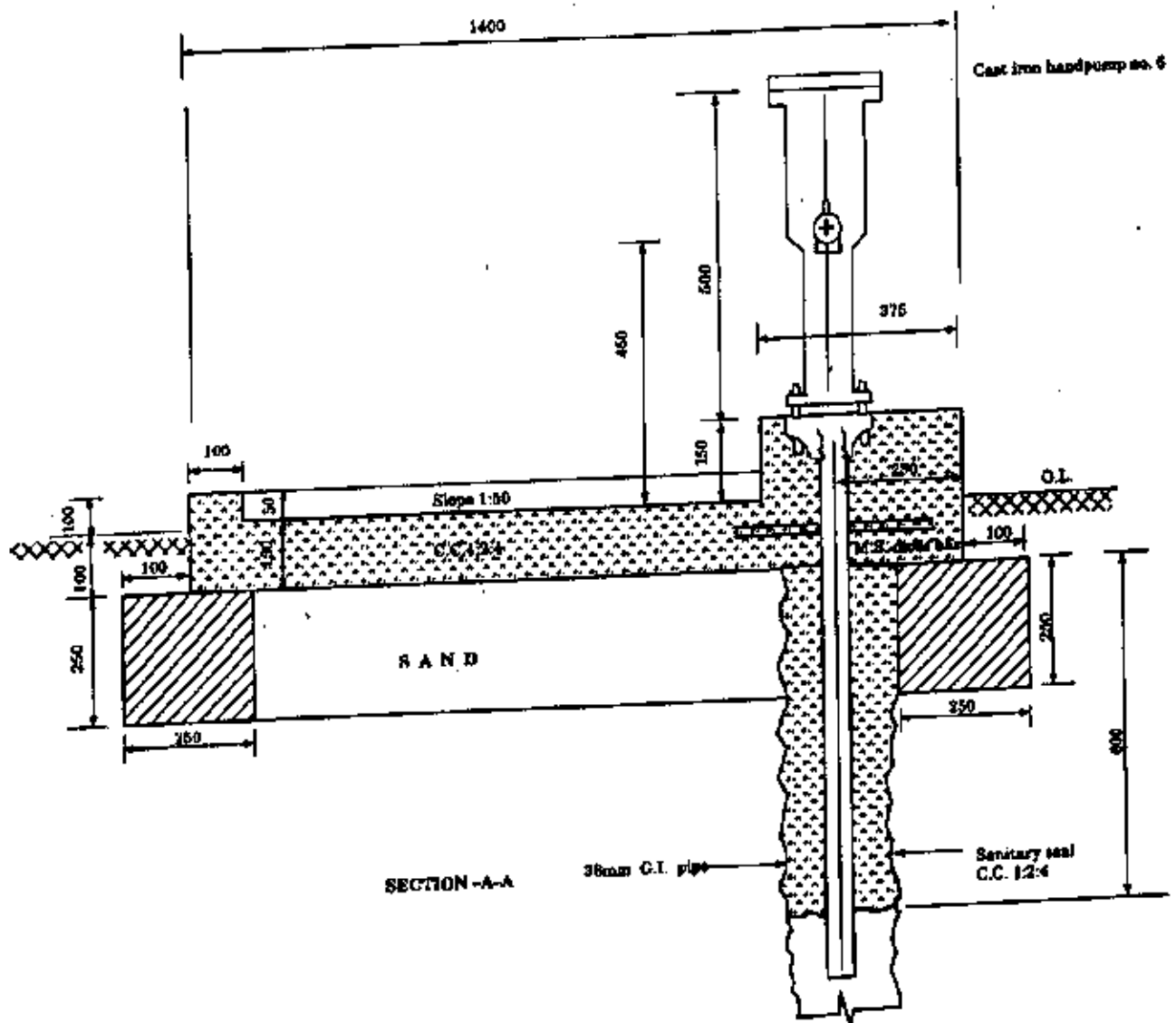


FIG. 31.3 SUPER STRUCTURE OF HANDPUMP TUBEWELL

- Sand trap - a 3 meter long 38mm dia PVC Pipe will be used as sand trap with the bottom end capped.
- Screens - 38 mm dia PVC well screens of recommended slot size will be used. The length of screen shall be as per design and direction of the Engineer-in-charge.
- Well pipe - 38 mm dia PVC pipes of approved Brand with threaded or male/female joints. PVC well pipe must conform the British Standard BS 3505.
- Top pipe - a piece of 1.50 meter long 38 mm dia GI pipe of approved Brand shall be used as top pipe (for fitting the hand pump on it) fixed to the PVC well pipe with a socket adapter. The top pipe shall have a 250 mm long mild steel crossbar welded to it and to be set or embedded into the concrete platform.
- Sanitary seal - a 0.60 meter deep sanitary seal around the top of the G.I. pipe.
- Platform - One cement concrete platform in/c drain shall be constructed over the tube well as per design.
- Pump head - One No.6 cast iron hand pump.

f) Sanitary Seal :

Immediately after lowering of the tube well fixtures, a sanitary seal shall be provided inside the top portion of the bore hole around the G.I. pipe. The sanitary seal shall consists of concrete mix in proportion 1 : 1.5:3 and shall have a total length of 0.60 meter below ground level as per design.

g) Well Development :

The well shall be developed properly by any effective approved method. Development is the process of surging the well to remove fine sand and clay adjacent to the screen and on the screen up to the satisfaction of the Engineer-in-charge. Proper development means easy pumping of water at the rate of minimum 25 liter per minute with a No.6 hand pump. The water shall be clean, sand and turbidity free. The development shall be continued till a satisfactory yield is obtained. Any improperly developed or non-developed well shall not be accepted.

h) Collection of Water Samples :

Water samples will be collected from the well, after it has been properly developed and sand free water is obtained, in the following manner —

- a) one clean bottle will be filled gently with care so that air does not mix with water and the bottle shall be tightly sealed immediately afterwards.
- b) another acidified bottle will be filled upto 3/4 th of its volume with care so that water does not spill out from the bottle and then tightly closed.

The samples so collected should be sent to the Laboratory of BUET or other recognised laboratory for analysis and other necessary tests like arsenic test etc. within 24 hrs. of collection.

i) Disinfection :

After collection of water samples, the well shall be disinfected by pouring in a solution containing 1 kg of bleaching powder. The solution shall stand for 12 hrs inside the well where after the well shall be pumped for at least 6 hrs.

ii) Final report :

The final report shall contain a detail description of the well, including the total depth, the location of the screen with type and slot size, complete boring log, mechanical analysis of soil

samples, static water level and water quality report. The final report shall be prepared by the contractor and countersigned by the Engineer and the contractor jointly. The final report shall be completed within one week after finalization of lowering of the tube well.

31.3.2 SHROUDED PRODUCTION WELL

a) General :

The shrouded production well shall be installed strictly as per design obtained from the test results of the observation well and approved by the Engineer-in-charge.

b) Well site :

The production well shall be installed at the location indicated to the contractor by the Engineer. It must be taken into consideration that the horizontal distance between the test tubewell and the production well shall not be more than 5 meters unless otherwise instructed by the Engineer-in-charge.

c) Drilling of the Tube well :

Drilling must be done by power rig. Methods of drilling will be reverse circulation. Methods other than reverse circulation may be applied only for wells deeper than 152 meters.

The boring diameter shall be according to the design. All boring must be done in presence of the supervising staff of this department.

The bore hole shall be truly vertical to the extent required so that the casing and screen when duly installed in the completed well will be sufficiently vertical to comply with the requirements of these technical specifications.

The contractor shall monitor the progress and resistance of drilling and the cutting samples brought of the surface. The contractor shall make a record of the strata penetrated and the depth of any changes thereof below the ground surface. The cutting samples will be collected and placed in a compartmented wooden sample box with depth marked in sufficient quantity (mini 500 gm each) from every 3 meter depth of penetration and at every change of formation. The contractor shall place each of the said samples in a plastic bag with a removable seal and shall then place the said plastic bag containing the sample in a second plastic bag together with a clearly written and durable label identifying the location of the well and the depth of strata from which the cutting sample was derived. The contractor shall deliver two copies of the log of the strata penetrated to the Engineer-in-charge who will then prepare the final design of the well.

d) Protection of Borehole :

Drilling mud shall be used in order to -

- support the sides of the well prior to installation of the casing and screen.
- ease the washing up of the cuttings from the borehold to the surface.

e) Lowering of the Tube Well :

All materials to be supplied by the contractor must be brought at the site prior to the start of well construction and approved by the Engineer-in-charge before assembling for lowering. Without prior approval of the Engineer-in-charge no materials can be assembled for lowering of the tube well.

Immediately after drilling the well to the specified diameter and depth, the contractor shall progressively assemble the casing, screen, sand trap, bail plug, reducer etc. according to the details shown in the final design, Figure F4. The adjacent pieces shall be joined together so that

the axis parts of the assembly are collinear and so that the assembly is capable of passing the test for alignment.

The contractor shall progressively lower the assembly into the drilled well so that finally the complete assembly is suspended with screen and casing located at the depth shown in the final design and the base of the assembly is clear of the bottom of the hole. The top of the well casing shall be lit between 0.90m and 2 m above ground level as directed by the Engineer-in-charge.

Centralizers, consisting of four leaves 10mm dia M.S. Rod will be fitted and fixed at 6m

intervals along the full length of the casing/blind pipe and at 3m intervals along the full length of the strainer as per drawing and design (Figure 31.4). Additional 4 Nos. 12mm dia M.S. Rod will be welded over the full length of the strainer/screen. The outer diameter of the centralizers shall be such that a minimum clear cover of 38mm remains all around between the borehole and the centralizer.

Blind pipe, strainer, housing pipe, sand trap reducer, bail plug etc. must be used as per approved design, quality and specification. In assembling the fixtures of the well socketing and welding shall be done properly using accepted and standard practices. All welds shall be of adequate strength free of blowholes, soak and other inclusions and shall be continuous around the circumference of the strainer or pipes. For welding of the stainless steel strainer, stainless steel welding rod shall be used.

On completion of the well and finalisation of all tests and development works, the contractor shall supply and weld a 6mm thick Ms. cap at the top of the housing pipe to prevent entrance of any foreign materials.

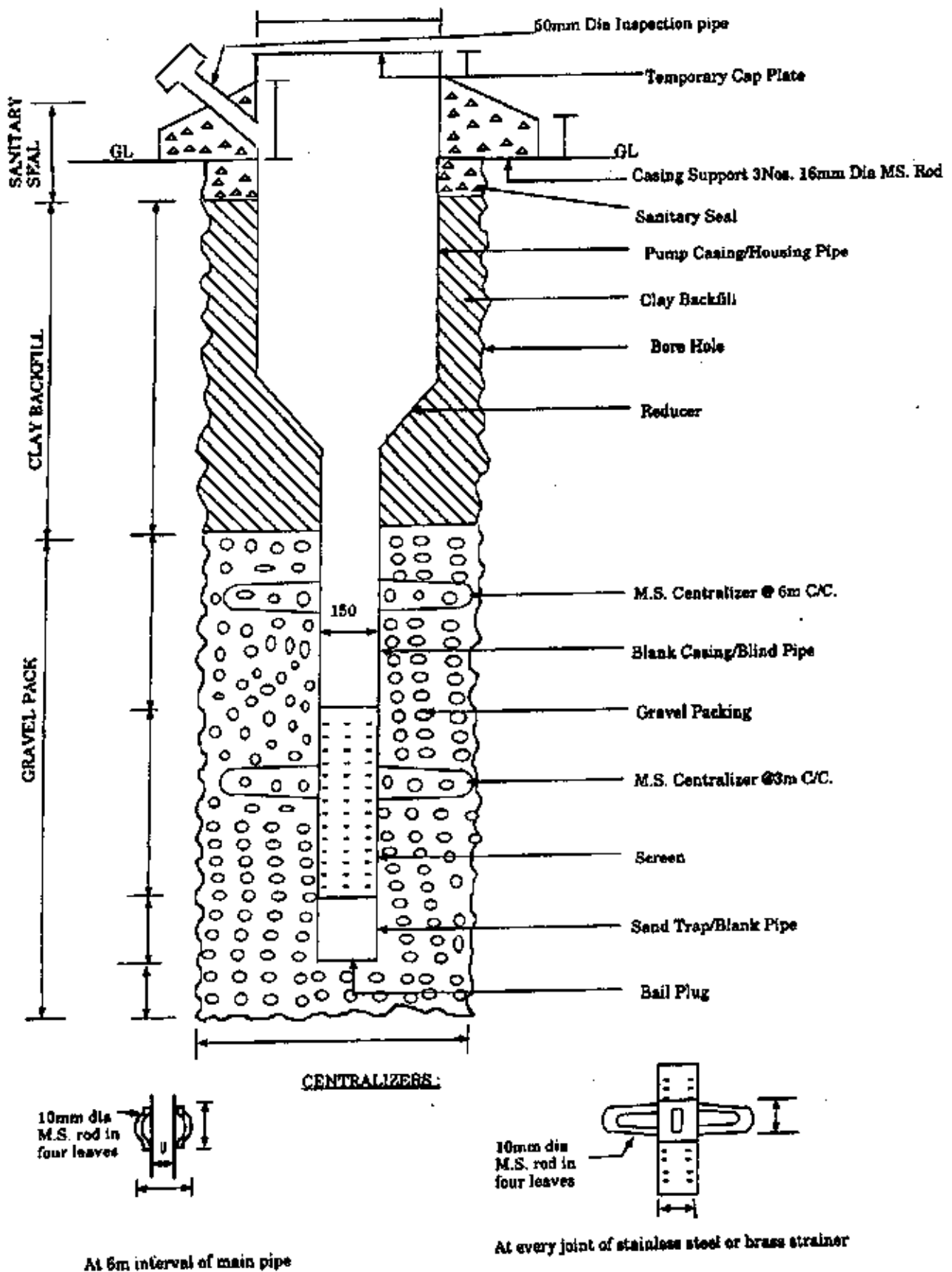


Fig. 31.4 Typical Cross Section of A Shrouded Production Well

n) Verticality Test :

The test shall consist of lowering a cylindrical pipe of external diameter between 1.3mm and 1.5mm less than the internal diameter of that part of the assembly whose alignment is under test and of length 12m down the assembly without binding. Suspension height should not be less than 3m or as advised by the Engineer-in-charge. This test is to be done before pouring down the shrouding materials.

The maximum allowable horizontal deviation from the axis of the casing at the base to a vertical line drawn through the same axis at the top of the casing shall not exceed 50mm at any point within the pump casing.

g) Gravel Packing :

i) Gravel Pack Materials

Gravels to be installed shall be composed of sound, durable well rounded particles, free of silt, clay, organic matter or other deleterious materials. Gravel of lime stones or other calcareous materials will not be allowed. The gravel shall be well graded as per design and be approved by the Engineer-in-charge which may be required due to the gradation of particles in the aquifers to be developed.

Gravels should be supplied after getting result from the test tubewell. Also the contractor shall conduct sieve analysis for relevant aquifers encountered during drilling, to the approval of the Engineer-in-charge and shall prepare gravel pack material in accordance with the results of these analysis in sufficient quantity.

The uniformity co-efficient of gravels shall be within the range of 1.8 to 2.5 and graded pea gravels should pass through 10 mesh retaining on 40 mesh. Gravel of crushed stone will not be allowed. The minimum thickness of the gravel pack should not be less than 75mm and maximum should not be more than 100mm.

ii) Placing of gravel pack

Immediately after lowering the casing and screen assembly into final position and after completion of the fitting and welding work in any well drilled with driller's mud, the contractor shall introduce water into the well and shall displace and dilute the mud until the consistency is such that gravel introduced into the well at the top will fall to the bottom of the well without bridging between the side of the borehole and the screen or casing. The method of replacing the mud shall be properly adapted so that mud from all locations to the bottom of the borehole is diluted so that upward velocity of mud and fluid in the annulus between the casing and screen assembly and the side of the borehole will not unduly impede the downward movement of the gravel from the top of the well.

As soon as the fluid density and viscosity have been reduced to acceptable values, the contractor shall while maintaining an upward flow of water in the annulus outside the screen and the casing assembly, fill in the said annulus with specified gravel either at the open end of the well or into pipes provided for the purpose. The contractor shall continue to add gravel until the annulus between the casing and screen assembly is gravel packed to not less than 9 meters and not exceeding 15mm contractor shall maintain the upward flow of fluid through the gravel placed into the annulus by addition of water until such time as settlement of the gravel in the annulus has ceased and the rising flow at the surface of the annulus becomes clear as to the satisfaction of the Engineer-in-charge. The contractor shall make a record of the quantity of gravel placed into the well in an approved form as suggested by the Engineer-in-charge.

h) Backfilling of the Borehole :

The open space between the tubewell and the borehole, from the top of the gravel pack upto the bottom of the sanitary seal shall be backfilled with selected withdrawn soil or with local clay. The backfill shall be free of any hard lumps or stones and shall be subject to the approval of the Engineer-in-charge.

i) Sanitary Seal :

The sanitary seal is provided on the top of the backfill of the tubewell. The sanitary seal shall have a minimum depth of 6m, measured from the ground level. This is done with concrete of proportion 1: 1.5:3 with cement, syllhot sand and brick chips. The casing and screen assembly shall be maintained suspended from the rig or other plant until completion of the gravel pack, clay backfilling but not when casting the sanitary seal.

ii) Development of Wells :

i) General

The purpose of developing the well is to clear the well water from all impurities and turbidities and to gain the optimum yield from the well. Development also rectifies any damage to or clogging of the water bearing strata which occurs as a side effect from the drilling. It also increases the porosity and permeability of the aquifer around the well. Development also helps to rearrange the formation particles of the aquifer around the screen of the well.

Development shall be carried out within 24 hours of completion of shrouding with a pump and motor that is capable of producing 300% of the design capacity of the well. There are various methods for developing well like Air lifting, Over-pumping and High velocity water jetting.

ii) Development by Air-Lifting (with compressor)

Development by air-lifting shall be performed by using an air-compressor with a minimum continuous output of 70 cubic meters per hour at a pressure of not less than 35 kg per square centimeter. The compressor shall be equipped with means of controlling and changing of the air output and a hose pipe assembly of minimum internal diameter of 40 mm at the free end of which it is capable of discharging the required amount of air into the casing and screen assembly at a depth equal to the lower most part of the screen. Compressor shall be operated in such a way that air is discharged at various levels of the screen position at intervals not exceeding 1.5 meters, to cause an upward movement of air and water sufficient to carry particles from the drilling mud used and sediment from the aquifer or any other source to the satisfaction of the Engineer-in-charge. The air-lifting operation shall be stopped at regular intervals and the screen and casing assembly shall be pressurized with a pressure not exceeding 10 kg per square centimeter in order to create a two directional movement of water through the screen, whereby the risk of sand bridging in the gravel pack will be minimized. This operation should continue not less than 8 hours and until the well yields sufficient quantity of sand free water.

The accumulation of sand particles in the bail plug should be monitored from time to time and shall be removed by means of a sand bailer of approved pattern so much that only a negligible amount remains. The air-lifting operation shall have to be continued until the water brought to the surface becomes significantly free from sand, silt drilling mud or other materials and until the amount of materials accumulated at the bottom of the well has decreased to negligible amounts.

iii) Development by Over-pumping

A turbine pump having a capacity of 200 m³/hr. is to be used for developing the well by over-pumping. The pump shall be installed in the well to be developed with its suction at a depth below the dynamic water level.

Pumping shall commence at a rate of approximately 50% of the normal steady pumping rate and shall be gradually increased until the intake of the pump is exposed above the water surface. The pump shall then be stopped and the water allowed to surge into the well from the aquifer and back down the discharge. The amount of sand in the water discharged from the delivery pipe should be observed carefully.

The base of the casing and screen assembly is to be sounded to assess the amount of sand accumulated at the base there of and the same shall be removed by means of a sand bailer of approved pattern so much that no more sand is left in the base of the sand assembly.

Over pumping shall be carried out along with treatment of calgon or sodium Hexa-meta-phosphates. The Sodium Hexa-meta-phosphate (SHMP) shall be brought into solution with clean water before placing in the well. Placing shall be by use of tremie pipes at the screen level after which the screen and casing assembly shall be repeatedly pressurized in order to drive the solution into the gravel pack and the formation. The amount of dry SHMP to be used for treatment shall be 50 kg dissolved in 1000 litres of water and placed in accordance with the above direction for first treatment and 25 kg for following treatments. This solution shall be kept in the well undisturbed at least for 24 hours. After that overpumping should be carried out to attain a well yield of at least 1.5 times the designed capacity at least for 4 hours and then a step drawdown test should be carried out for 2 hours in variable discharges. /

Development treatment should be continued until the water is free from turbidity, meets the sand contents requirements and yields at least the design capacity at acceptable flow losses.

k) **Well Testing :**

i) **Equipments**

Following development the water levels and well discharges are to be measured and recorded properly. For this purpose, a pump and motor capable of producing 300% of the design capacity, also equipped with suitable orifices and manometers, shall be used for accurately measuring the well discharge.

ii) **Step Draw Down Test**

A step draw down test is to be done before starting the development procedures to establish the well condition before development.

After completion of each development treatment a step draw down test shall be performed by pumping water at different rates until at least 250% of the design capacity is reached as per following schedule :

- i) 80% of design capacity for 6 hrs.
- ii) 100% of design capacity for 6 hrs.
- iii) 150% of design capacity for 6 hrs.
- iv) 200% of design capacity for 6 hrs.
- v) 250% of design capacity for 6 hrs.

or as per instruction of the Engineer-in-charge. The water level in the well prior to commencement of pumping and then simultaneous readings of water levels shall be recorded properly.

iii) **Long Term Pumping Test :**

After completion of step draw down test, the long term pumping test is to be started. The well shall be tested and pumped at discharge rates which will be determined by the Engineer-in-charge. The pumping test shall continue for a minimum of 24 consecutive hours and upto three days as directed by the Engineer-in-charge. If the test is interrupted during the specified period for any reason, the water level will be permitted to recover and the test shall be repeated. Upon completion of test pumping the pumping shall be ceased and simultaneous readings of the water level in the well shall be recorded as per instruction of the Engineer-in-charge.

l) **Selection of Pump :**

The capacity of pump should be such that the entrance velocity of water rushing top the strainer will not be more than 0.10 feet per second.

m) **Record of Measurements :**

i) **Record of Construction Details**

On completion of the work, the contractor shall furnish all recorded samples and measurements to the Engineer-in-charge. A graphic log and description of the well construction (as built), adequately dimensioned with details on strainer, gravel pack and grain size distribution of the shrouding verticality test data, pumping test data, including a well log and description of the formation, shall be furnished in duplicate as per prescribed form.

ii) **Development Data**

The following data shall be presented :

- a) Method of development procedure
- b) Static water level at the start of development
- c) Time of pumping for each rate or step of pumping operation
- d) Water level at each rate of pumping
- e) Comments on quality of water at each stage of pumping i.e. sand content and turbidity.
- f) Water level with time of recovery after development.

iii) **Pumping Test Data**

Discharges (during pumping) and water levels shall be measured in the well at the following intervals :

- a) Prior to starting of the pump - i) hourly for at least 2 hrs. ii) immediately before pump is started.
- b) During pumping - i) every one minute for first 20 minutes. ii) every two minutes for next 20 minutes. iii) every five minutes for next 20 minutes. iv) every ten minutes for next 60 minutes. v) every 30 minutes for next 60 minutes vi) at one hour intervals for the balance of pumping.
- c) After pumping stopped - The same intervals of time are to be observed as during the pumping period (point b), starting the hourly reading after 3 hours have passed.

iv) **Water Quality Test :**

i) **Sample collection**

Two sets of water samples, one in clean bottle and another in acidified bottle of 100 cc shall have to be collected and sent to the recognized laboratory for water quality test within 24 hrs. of sample collection with sealed cover and labelled with number, location of the well, time and date of collection.

ii) **Disinfection :**

i) **Time of Disinfection**

On completion of test pumping and collection of water samples, arrangement for disinfection of the well is to be done by introducing sufficient solution of chlorine of sufficient strength to establish a free chlorine residual of 150 parts per million.

ii) **Chlorine Solution**

The solution shall be made up from an approved compound as per instruction of the Engineer-in-charge. The compound shall be new and supplied in factory sealed containers free of corrosion each of which states the percentage of available chlorine in the compound within the said container. The solution shall be administered to the well by pouring a quantity of solution containing the total required quantity of available chlorine down the well from the surface.

iii) **Duration of Disinfection :**

The chlorine solution shall remain in the well for 24 hrs after which the chlorine solution shall be pumped out of the well. The pumping shall continue until the outlet water is free from chlorine smell.

The chlorine solution which is pumped out immediately after pump start shall be returned to the well for recirculation.

CHAPTER 32

ANTI-TERMITE WORKS

32.1 GENERAL NOTE

Termites are cellulose-eating social insects. Although they are referred to popularly as white ants, they are not closely related to ants. Termites, which number in total about 1900 species, are distributed widely, reaching their greatest abundance in number and species, in tropical regions around the world. Bangladesh being a tropical country is not free from this menace. The damage caused by them is seldom apparent until it reaches a serious stage. By the time the termite damage becomes visible, costly repairs and replacements are usually needed. The loss caused by these tiny insects runs into crores of Takas annually.

32.2 IMPORTANCE

The food of termites is mainly cellulose, obtained from wood, grass, leaves, humus, manure of herbivorous animals, and materials of vegetative origin (paper, cardboard, cotton etc.). As such termites are dangerous for any building because they eat up its wooden members. Termites damage non-wood materials as well such as rubber, plastics, polythylene, plasticised PVC, nylon and polypropylene including cellular plastics, thus making all kinds of pipes and electrical wirings vulnerable to damage inside walls, concrete etc. In some countries the loss caused due to termites is estimated to be as high as 10% of the capital outlay of the buildings.

32.3 TERMITE CONTROL

Termites are classified into two categories :

- (a) Dry wood termites
- (b) Subterranean termites

Dry wood termites : These termites live in dry wood in small colonies without maintaining any connection with the soil.

Subterranean termites : These termites have their main colonies in soil, under ground. They can not survive without maintaining any connection with their prime colonies in the soil. However they travel in search of food, mostly wood and cellulose matter through shelter tubes or funnels in other materials. These termites enter the buildings through foundations or from ground adjacent to the buildings and advance upwards through the cracks in floors, cracks in masonry and joints etc.

For effective control, it is essential to determine whether the termite is a subterranean or a wood-dwelling as treatment methods differ.

Dry-wood termites are difficult to control. Preventive measures include the use of chemically treated wood in building construction and the use of paint or other durable finish to seal cracks in wood surface.

As eradication of subterranean termites is not feasible, control of those is best achieved by denying them access to the building. This can be achieved by the use of chemical barriers which prevent the insects penetrating into buildings. Maximum protection, at a cost of less than 1% of the total building costs, is provided by creating an insecticidal barrier round and under the foundations. In the USA, complete protection for more than 30 years has been achieved.

32.4 ANTI-TERMITE TREATMENT

Anti-termite treatment may be divided into two categories :

- (a) Pre-construction treatment
- (b) Post-construction treatment

(a) Pre-construction treatment

This treatment is started right at the initial stage of construction of buildings. Pre-construction treatment can be divided into following operations :

- (1) Site preparation
- (2) Soil treatment

Site preparation : To minimize the risk of termite attack, it is important to deprive them of food and moisture. The site should be properly drained and any conditions leading to the maintenance of high soil moisture around the building avoided. The removal of all forms of wood, including roots, stumps, logs and other debris is important. This is essential since the termites thrive on these materials. If termite mounds are detected these should be destroyed by use insecticide solution.

Soil treatment : The best and only reliable method to protect the building against termites to apply a chemical treatment to the soil at the time of construction of the building. This should be done in such a way that a complete insecticidal barrier is created around the foundation walls, under floors, and at all points that are vulnerable to termite entry. For satisfactory results, the applications of insecticides should be carried out by the professionals.

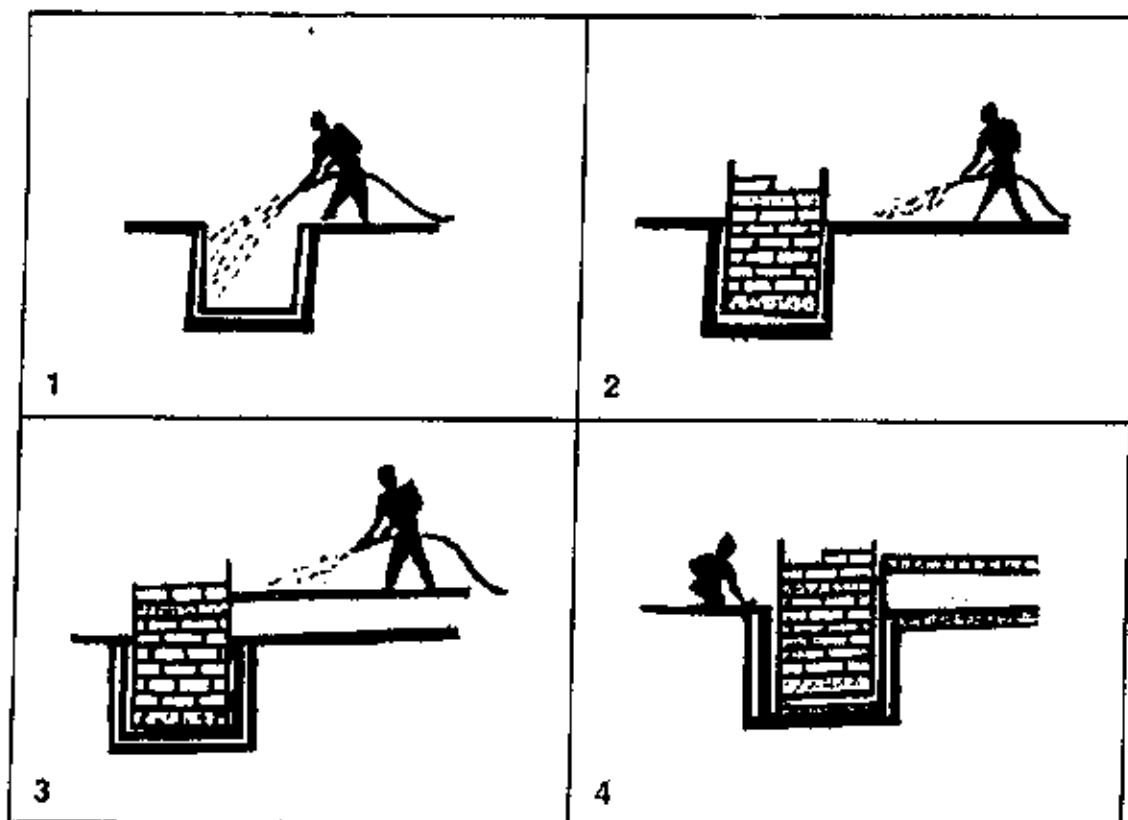
Procedure for Pre-Construction Soil Treatment

The best Government registered chemicals (insecticide/termiticide) available in the country for termite control is organo chlorine compounds such as Dieldrin, Heptachlor, Chlordane, Curdane 20wp, Dursban 20EC, Pyriphos 20EC, Cislin, Actelic 40EC, Neocidol 600EC etc. which are all members of infamous 'DIRTY DOZENS'. By use of Dieldrin, complete protection work for more than 30 years has been achieved in the U.S.A. Dieldrin is highly toxic and is responsible for environmental pollution. In the recently concluded 'RIO SUMMIT ON EARTH', it has been decided to completely phase out such chemicals over a period of time. Some of the newly developed safer products for termite control are in use in the advanced countries with lesser period of protection.

1. **Foundation Trench Treatment :** The First step in the treatment of soil in new constructions is to spray the walls and the base of the foundation trenches with any one of the chemicals before the foundation walls are raised. (Illustration No. 1)
2. **Floor Treatment :** The treatment of soil under the floor is done in the following manner :
 - a) If the locality, where the building is to be constructed is badly infested with termites, it is desirable to spray the natural soil surface of the site with any one of the chemicals. This operation will create an additional barrier in the lower strata of the floor. (Illustration No. 2)
 - b) After the earth has been filled in to raise the plinth level and just before laying the brick soling for the floor, the entire plinth is sprayed over with any one of the chemicals. (Illustration No. 3)
3. **Internal Perimeter Treatment :** Trenches of suitable depth are made along the internal perimeter, both sides of the partition walls and around the pillars, if any. Chemicals are applied to the trenches so as to create an insecticidal barrier.
4. **Extrenal Perimeter Treatment :** After the building is completed and the surroundings are levelled, a trench is made along the exterior foundation walls. Chemicals are added to the trench so as to

create a barrier. The depth of the trench will vary according to the depth of the foundation. (Illustration No.4)

5. **Additional Operations :** Laying of sanitary lines, water pipes, underground cables etc. and making holes in the walls and floors for the above purposes, create vulnerable points facilitating entry of termites. The treated surfaces may also be disturbed thus weakening the chemical barrier. Therefore, it is very important that all such places are thoroughly treated or retreated with chemicals.



It has been found that termites are able to dissolve lime mortar by means of acidulous secretions from their frontal glands, and either by physical or chemical means are able to penetrate into buildings.

Furthermore, surprisingly termites have found ways to flourish even in the most modern steel structures. They have penetrated bank vaults and safety deposit boxes to feed on cash and stock certificates.

Termites penetrate through minute cracks to get at anything containing cellulose as their food. Modern conveniences, such as air conditioning, are added incentives for termites to reproduce at record rate, and they are now found almost as frequently in urban skyscrapers as in rural structures equally.

Pre-construction soil treatment is more economical than treatment carried out in a completed building. Not only is costly damage done by termites but the treatment required to eradicate this menace in a completed building is a lengthy and expensive process. Moreover, by the very nature of its operation, Pre-construction soil treatment is more thorough. These advantages mean less worry, better termite control and long term saving.

32.5 PROTECTING BUILDINGS AGAINST TERMITES

The tiny termite in its quiet determined way damages countless homes and buildings and shops the resources of nations and peoples throughout the tropical and sub-tropical regions of the world. Within this vast area, as stated previously any building is vulnerable to termite attack, even those made of brick and concrete termites damage all forms of wooden structures as well as non-wood materials such as rubber, plastics, polyethylene, plasticised PVC, nylon and polyperpylene including cellular plastics, thus making all kinds of pipes and electrical wirings vulnerable to damage inside the walls, concrete etc.

Infestation by soil termites can be stopped effectively by the use of chemical barriers which prevent the insects penetrating into building from the soil below. As eradication of subterranean termites is not feasible, it is best achieved by denying them, access to the building. Maximum protection, at a cost of less than 1% of the total building costs, is provided by creating an insecticidal barrier around and under the foundations.

In areas of high termite activity, buildings left unprotected can become seriously infested within 2 to 3 years of construction. Post construction treatments are more expensive and difficult to carry out. The most effective and economical time to provide protection is during the planning and construction stages of building. It is therefore, the responsibility of architects and builders to ensure that adequate termite control measures are carried out and that their clients investments are protected. Termite proofing adds quality and value to any building for a very long period of time. Soil poisoning before and during construction is more prevalent because of its adaptability to large scale construction projects. The details of treatment of New Buildings as well as Existing Buildings are given below separately.

32.6 PROTECTION OF NEW BUILDINGS AGAINST ATTACK BY SUB-TERRANEAN TERMITES

Pre-construction treatment offers several important advantages :

1. Pre-Construction soil poisoning with Heptachlor 40wp/Curdon 20wp etc. is the only means of assuring complete chemical barrier below and around the structure.
2. Heptachlor 40wp treatment protects the structure before the insects gain entry thus eliminating the necessity of applying this protection later, and making structural alterations.
3. Thorough treatment of foundation trenches is easily accomplished. Crawl spaces and basements are exposed for thorough treatment before the concrete slab or floor is poured. Following are the steps given how to protect new buildings.

32.6.1 The Chemical Treatment

Whatever form of construction is adopted, it is essential to treat the soil with Heptachlor 40wp, Curdon 20wp, Chlorodene etc. beneath the building. Poisoning the soil produces a barrier through which it is difficult for the Termites to penetrate. When properly applied there is very little danger either to people or livestock from treated soil.

32.6.2 Overall Foundation Treatment

After the foundations have been excavated, apply the Heptachlor 40wp mixture (as prepared above) over the whole site, including the base of the trench for the foundation walls at the rate of 5 litres per square metre of soil. To obtain best result, the treatment should be carried out when the soil is fairly dry.

32.6.3 Treatment of the Foundation Walls

It is advisable to treat the Concrete and Sand-cement mortar used for foundation walls. To poison concrete and sand-mortar, simply use the Heptachlor 40wp mixture instead of the usual mixing water. There is no effect on the amount of water required, curing or strength. Use poisoned water only while preparing the concrete or sand -cement mortar for building the foundation wall or foundation concrete slabs and all concrete structures below the ground level and upto plinth level

after the foundation walls have been completed and before the floor is laid, spray the excavated soil on the inside of the foundations at the rate of 6 litres per metre run. Hardcore of other sub-foundation materials should also be treated at the rate of 5 litres per square metre before the floor is laid. Outside the foundation walls, treat the bottom of the trench at a rate of 6 litres per metre run. Treat the excavated soil at the same rate prior to backfilling of the trench.

For small scale work, the Heptachlor 40wp mixture can be applied with a large watering can fitted with either an ordinary rose or fish-tail. In case of large scale work involving large quantities of poison mixture, it can be mixed in empty oil drums and sprayed with the aid of engine driver centrifugal or gear pumps delivering 10-20 gallons per minutes in low pressure. Almost any kind of hose and many types of nozzle can be used provided they can deliver large volumes. Off, centre types of nozzle are preferred although a simple one can be improvised from a flattened pipe.

32.6.4 Treatment of Slab on Ground

After the ground has been filled the hardcore and the soil are treated with Heptachlor 40wp mixture as follows:

- Before casting the slab apply Heptachlor 40wp Mixture at the rate of 5 litres per square metre (1 I.G. per 10 sft) over the whole area to be covered by the building.
- Apply an extra amount of Heptachlor 40wp mixture along the inside of the foundation walls around plumbing and the well voids at the rate of 6 litres/ metre (4 I.G. per 10 ft run)

Figures 32.2 and 32.3 illustrate the various stages in the construction and treatment of this type of slab. If formwork is not used take care not to damage the sides of the excavation when spraying. It is advisable to use Heptachlor mixed water instead of plain water, while preparing the Cement-Sand-Mortar for giving complete protection from Termites.

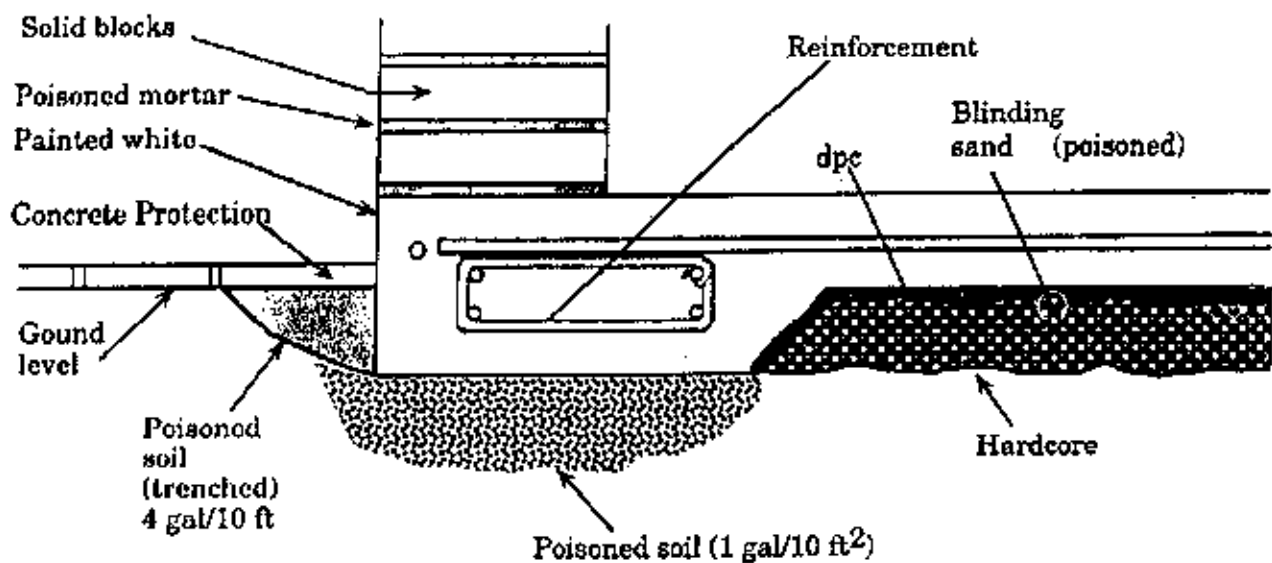


Fig. 32.2 Monolithic Slab Shallow Footings on Sandy Soil

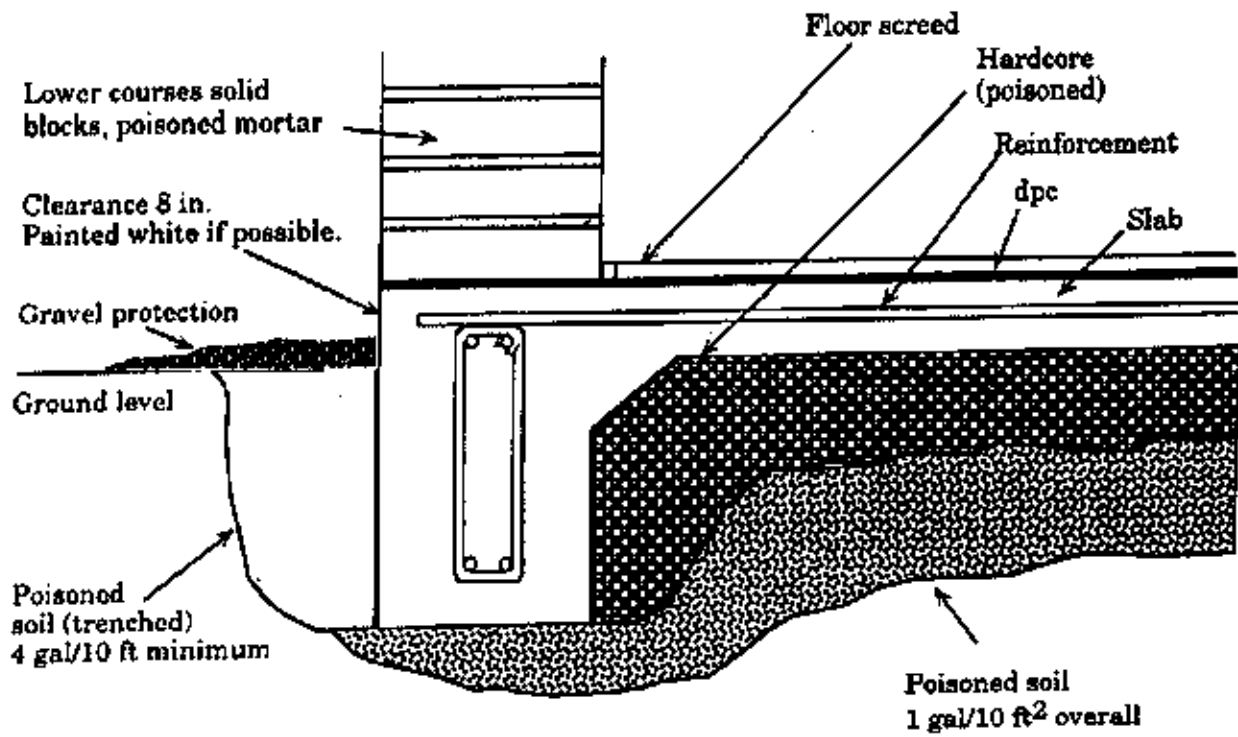


Fig. 32.3 Monolithic Slab Medium Depth Footings on Clayey Soil

The Dieldrin treatment is carried out after the foundation walls have been constructed and before the floor slab is cast. Illustrations given in Fig 32.4 and Fig 32.5 below :

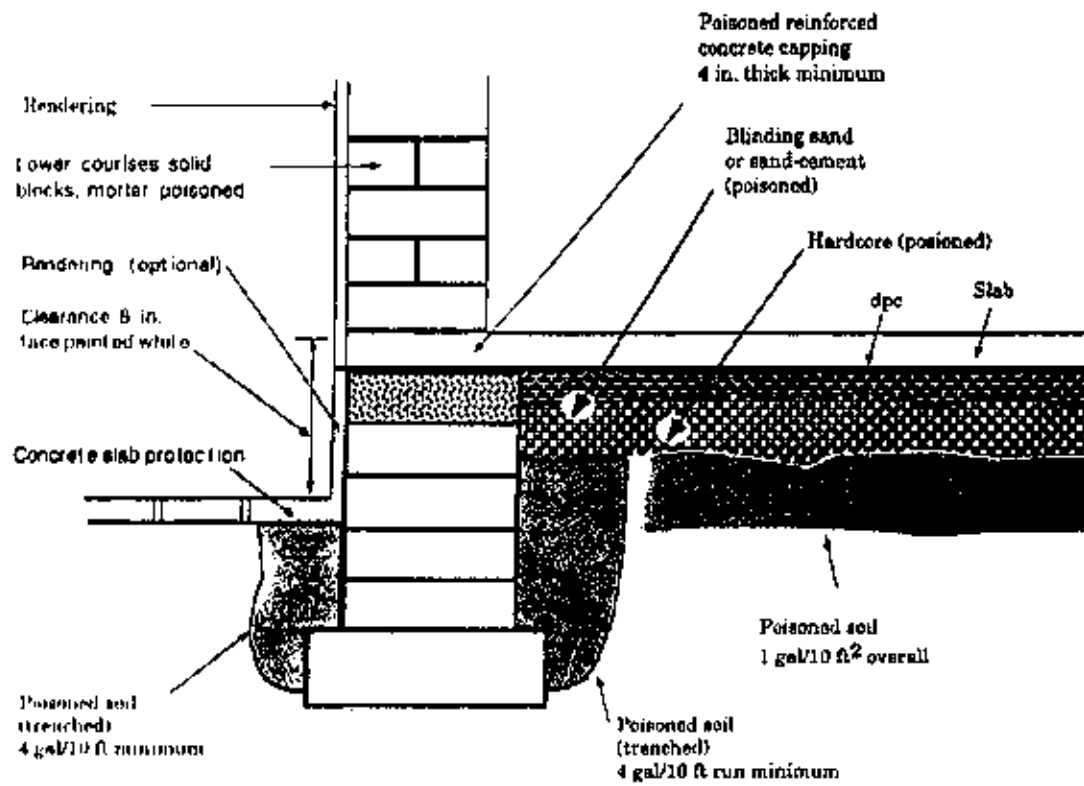


Fig. 32.4 Suspended Slab on Ground Construction

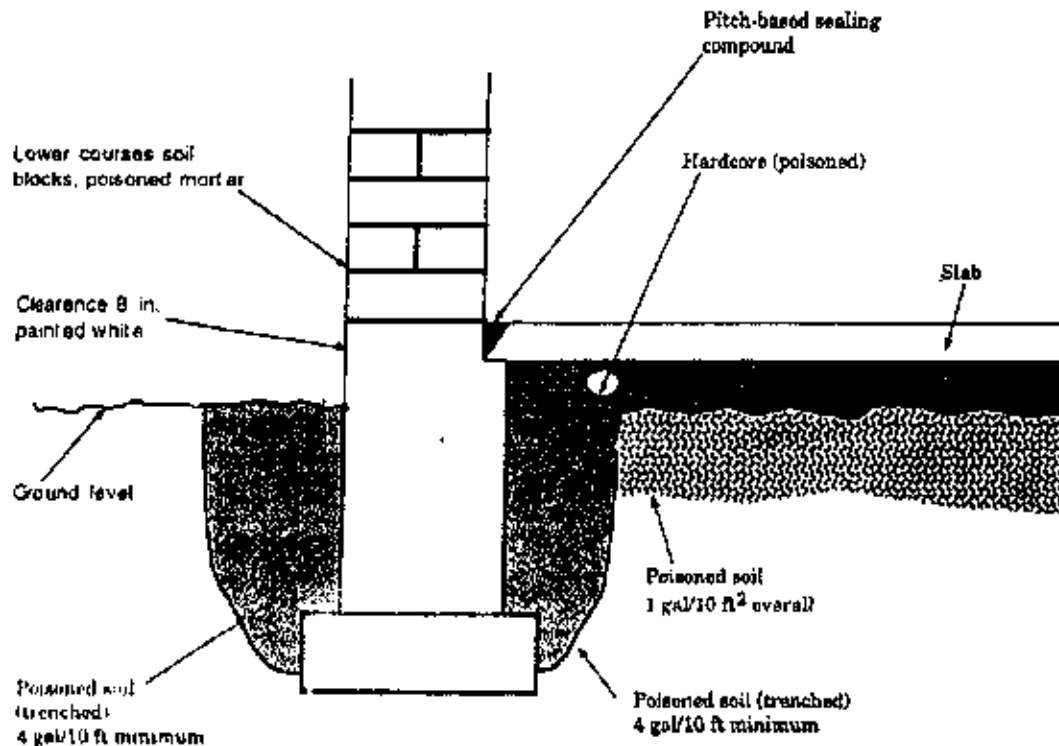


Fig. 32.5 Floating Slab-on-Ground, New Construction

32.6.5 Treatment of Water Pipes, Drains And Services

Where Water Pipes, Drains and other services emerge from the soil the surrounding soil should be well soaked with Heptachlor 40wp mixture, (Fig. 32.6), Electricity Cables should be enclosed in metal or PVC conduit and this should be surrounded by Heptachlor 40wp treated Concrete or Sand Cement. Where Pipes Penetrate through Walls or floors, the gap between the Pipe and the structure should be sealed with Heptachlor 40wp treated Sand-Cement-Mortar. The fitting of Termite shields to Pipes is useful specially in preventing the Termites using Pipes as bridges to gain entry.

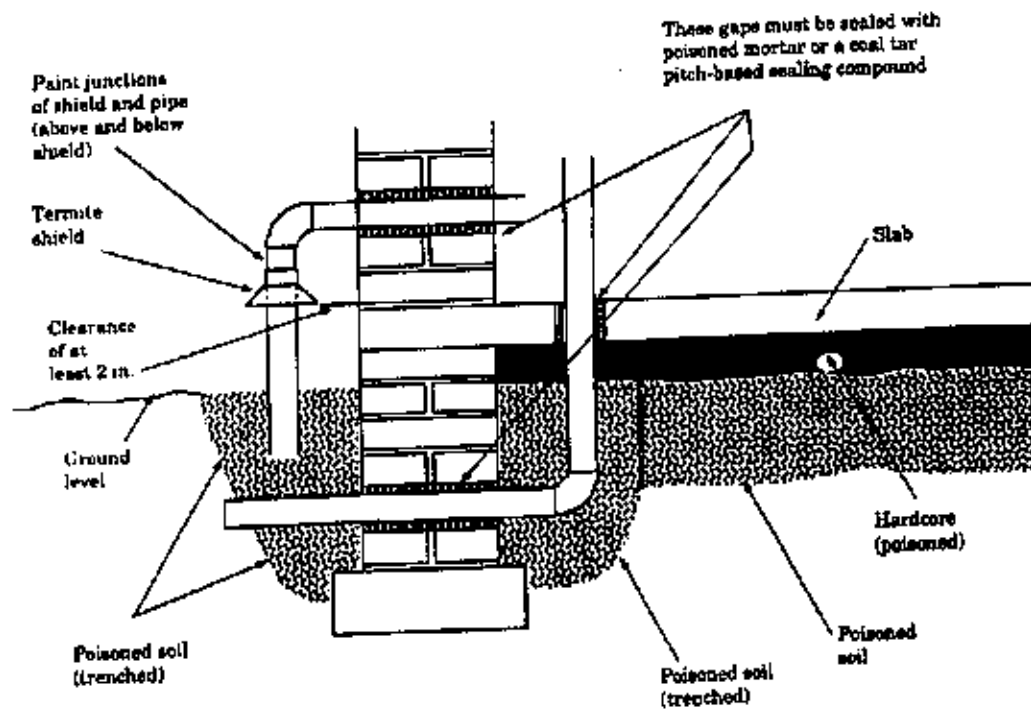


Fig. 32.6. Protection of pipes entering above and below Suspended Slab-on-Ground

32.6.6 Treatment of Bored Pile and Beams

On expansive Clay Soils, bored pile and beam construction is employed to prevent damages caused by the movement associated with this type of soil. Where possible, there should be a crawl space of atleast 18 inches beneath the ground floor. However, where this is not feasible and the beams have to be constructed close to the soil, the whole area of soil beneath the building should be treated at the rate of 1 gallon of Heptachlor 40wp mixed water per 10 sft. As the soil is clayee care must be taken to ensure that the ground is not sprayed at a faster rate than the Heptachlor 40wp-mixed water can be absorbed. If necessary, the surface of the soil should be roughened to assist absorption.

The Soil and any cushioning filled beneath the beams should be poisoned with an additional 4f.G. of mixture per 10 sft. This should be done before the beams are cast.

Shallow Trenches should be dug around the piles and the trench sprayed with additional poison water, also the soil as it is replaced in the trench. The exposed parts of the piles and the beams should be painted white. Illustration given below. Fig. 32.7.

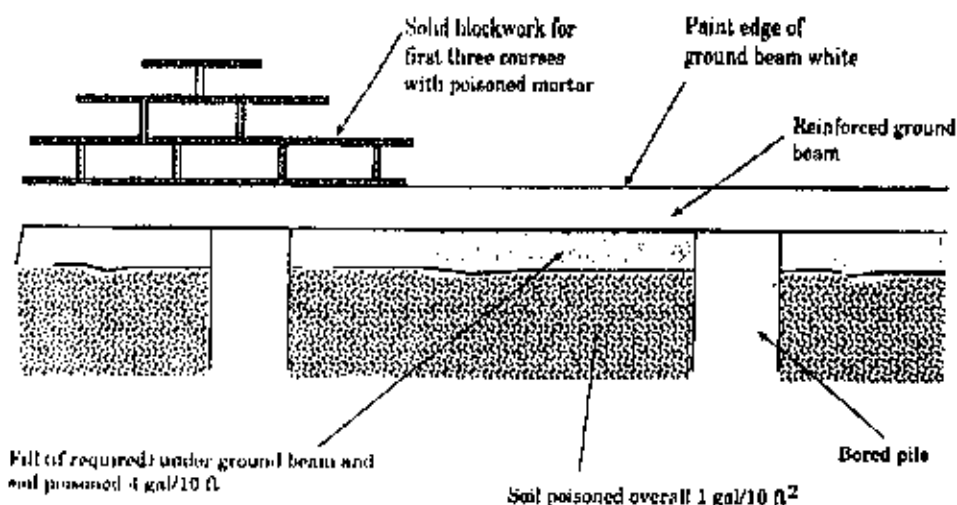


Fig. 32.7. Bored Pile and Ground Beam. No Crawl Space

Where it is possible to have a crawl space, beneath the ground floor, it is essential to poison treatment of the soil around the piles by trenching and using at least 4 gallons of poisoned water per 10 sq. ft. run. It is also advisable to poison the soil over the whole area beneath the building at a rate of 1 gallon per 10 sq. ft. If the crawl space is to be enclosed then the soil around the enclosing walls should be poisoned as described for the foundation walls. (see figure 32.8)

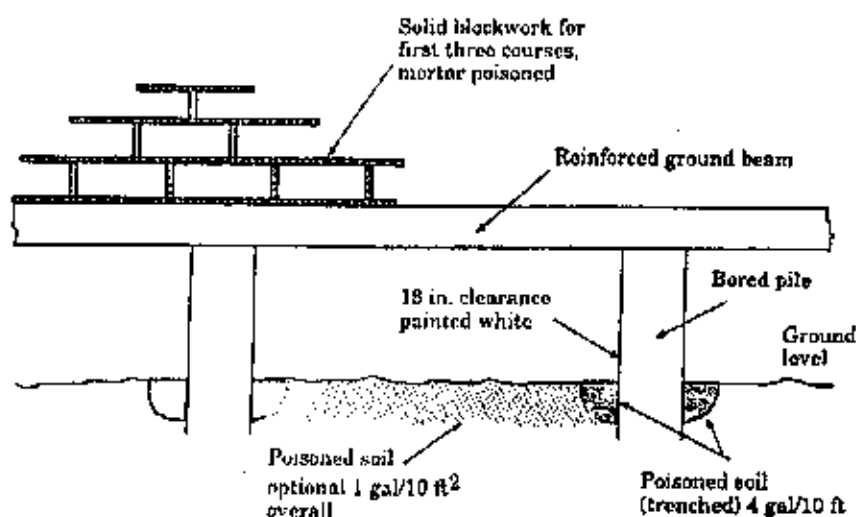


Fig. 32.8. Bored Pile and Ground Beam with Crawl Space

32.6.7 Entrance Steps, Garages and Car Porch

The soil underneath these structures should be treated in the same manner as described to the main building. If possible, Porches, Verandah and entrance steps should be so designed that the spaces beneath are not filled with soil, so that it can be inspected periodically. However, if this is not possible then either a gap of at least two inches should be provided between the main building and the additional structure or barriers should be constructed to force the Termites out into the open. Termites often penetrate at the junction of the additional structures with the main building.

32.6.8 Perimeter of the Building

It is advisable to have at least 8 inches difference between the ground level and the floor of plinth level. The exposed foundation wall should be plastered with poisoned-cement plaster, (mixture method discussed earlier). However, if this is not possible, the exposed foundation wall face should be kept clean and should be painted in a light colour, preferably with emulsion paint or cement paint.

Creepers, Climbers or other vegetation likely to provide means of access for termites should not be permitted to grow on or near building.

32.6.9 Walls

Cavities in walls provide means of access to susceptible materials for those Termites that are able to penetrate the ground floor defences. In the humid tropics blockwork walls are often constructed with hollow blocks but it is advisable to construct the bottom two or three courses in solid blockwork, using poisoned mortar.

Once the ground floor is protected against possible Termite attacks, it is necessary to protect the other floors, through careful protection pipes and fitting which connect the upper floors. Precaution should be taken to seal all entry points of such pipes, wires etc. on the first floor and other floors. Sealing with poisoned mortar around the pipes usually ensure reasonable protection.

32.7 PROTECTION OF EXISTING BUILDINGS

Although the best time to institute protective measures against Termites is during the construction of a building, it is not too late to take effective action even after the building has been in use for some time.

It is essential in the first place to make certain that there are no Termites present in the building. Close examination of all timber and the structures adjoining it should be carried out. Subterranean or soil termite can often be detected by the presence of earth tubes leading upto the timber where as dry wood Termites leave heaps of excreta pellets near the infested timber.

The protective treatment that can be applied to existing buildings includes some measure of soil poisoning, the provisions of barriers and the surface treatment of timber and other susceptible material.

32.7.1 Foundation and Floors

The extent to which the foundations and ground floors can be treated will depend on the type of construction. Slab-on-ground floors are the most difficult and suspended floors with crawl space underneath are the easiest to treat.

32.7.2 Slab on Ground

Effective treatment depends upon providing a barrier of poisoned soil surrounding the building. It should aim at making the barrier as impenetrable as possible to soil Termites. Care must be taken not to damage the foundation while performing treatment.

A Trench, roughly one foot deep and one foot wide should be dug about one foot away from the outside foundation wall. It should be dug in sections of about 20 ft. at a time, the soil being treated, replaced and properly consolidated before the next section is dug. Holes, 1 foot apart are made in the bottom of the Trench to a depth of 2 feet below the bottom of the Trench. The Trench is then sprayed with Heptachlor 40wp mixed water (1 : 40) at the rate of 4 gallons per 10 ft. run of the trench. The Trench is then refilled treating the soil with an additional 4 gallons of poison water per 10 feet run as it is being replaced. In this way a continuous belt of poisoned soil is produced around the building. The soil between the Trench and the foundation wall should be sprayed with poisoned water at the rate of 2 gallons per 10 running feet. The treated area of the soil should be covered with concrete, concrete slab or a thick layer of gravel. A clearance of at least 6 inches should be left between the top of the foundation wall (plinth level) and the ground and the exposed foundation wall face should either be plastered with poisoned mortar or painted with a light colour with emulsion or cement paint.

Whilst treating the soil it is essential to remove all wood and other debris. It is also essential to remove shrubs, creepers, vegetation, timber and trellis work that could serve as a bridge between the soil and the building.

Where pipes, drains and other services penetrate the ground floor slab and there are cracks or gaps between the pipes and the slab, Heptachlor 40wp mixed water (1: 40), should be poured down the cracks or gaps until the ground underneath is well soaked. After drying out, these cracks and gaps should be sealed with poisoned sand-cement-mortar. Where services pass through the foundation wall the junction should be well sealed with poisoned sand-cement-mortar. Open joints and cracks in the floor slab and between the floor slab and the walls should be flooded with poisoned water and after drying, the gaps should be sealed with poisoned cement mortar. Fig. 32.9 shows the schematic representation of the process.

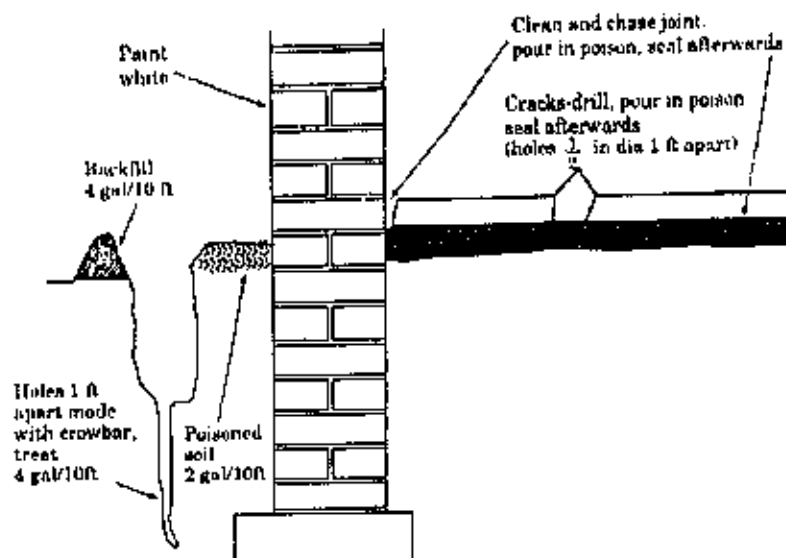


Fig. 32.9. Floating Slab-on-Ground Treatment of Existing Construction.

32.7.3 Basements

The soil around the outside of the basement walls should be poisoned as described for new construction. Gaps and cracks should be treated as described for slab-on-ground construction.

32.7.4 Protection of Timber, Doors and Windows

Not very much can be done in the way of treating previously untreated timber. Roof timbers can be treated by painting with creosote or a white spirit solution of Dursban 20EC, Pyhiphos 20EC or Timberin etc. This brush treatment does help to prevent infestation by dry-wood Termites.

Other structural timber can also be brush treated with white spirit and Dursban 20EC, Pyhiphos 20EC or Timberin etc. solution. After the treated timber has dried out it is advisable to paint the timber. In the case of timbers in the enclosed and wall spaces, boards or panels should be removed to permit access to the timber.

The doors and windows frames (CHOWKAT) should be removed from the wall. The plasters on these walls should be removed and a new plaster, prepared with sand-cement and Heptachlor 40wp water should be put, after thoroughly treating the exposed wall surface with poison water. After the poisoned plaster is set and dry, the timber frames for doors and windows should be replaced. This will give protection from fresh infestation of Termites.

32.7.5 Eradication of Termite Infestations

It is essential to discover the full extent of infestation and the type of Termite involved. The characteristic signs of soil Termite attack are the earth tubes and runways, which when traced back, provide information on how the Termites managed to penetrate into the building. Infestation by soil or subterranean Termites are eradicated by poisoning the soil in which they live and reinfestation is prevented by providing barriers of poisoned soil and by sealing the gaps through which the Termites could again penetrate the building.

32.7.6 Subterranean or Soil Termites : Slab-on-Ground Construction

It is very difficult to treat an infestation in a building with slab-on-ground construction in the first place Heptachlor 40wp mixed water (1:40) should be poured into any-gaps or cracks that can be found. If the Termites have penetrated through the holes or cracks that are too small to be treated this way, holes 1 inch in diameter and not less than 1 foot apart should be drilled through the slab in their cavity, taking care not to damage pipes or cables. As much Heptachlor 40wp mixed water as possible should be poured through these holes. After treatment the cracks, gaps and holes should be sealed with poisoned sand-cement-mortar.

If signs of infestation continue after these treatments, it is probable that there are nests of termites beneath the slab. They can be destroyed by drilling holes through the ground floor slab and injecting quantities of Heptachlor 40wp mixed water (1:40) through these holes under pressure.

32.7.7 Ground Floors with Crawl Space Underneath

Eradication and treatment is fairly simple in this kind of floor. Termite hills should be destroyed and treated with poison water, the cavities should be filled in and the ground compacted. The ground beneath and around the building should also be poisoned as described earlier. Special attention must be paid to those parts of the structure through which the Termites have been able to penetrate.

32.7.8 Porches, Terraces, Verandhas and Entrance Steps

Infestation of buildings frequently occurs through these additions to the main structure. The underlying soil must be poisoned, especially where it adjoins the main structure. Where it is not possible to fill parts of the floor and expose the underlying soil for treatment with Heptachlor 40wp, holes 1/2 inch in diameter and not less than 1 ft. apart should be drilled and Heptachlor 40wp solution forced through the holes. Afterwards, the holes should be sealed with poisoned sand-cement-mortar. The soil under Porches and Entrance steps should also be treated in the same manner. A barrier of poisoned soil should be laid around the structure linking up with the barrier around the building as described for new construction.

32.7.9 Repair and After Treatment

Destroying the Termites in the soil beneath a building and providing chemical and a technical barriers against further attempts of penetration eradicates soil Termites from a building. Any soil Termite left behind in the fabric of the building will perish unless they can re-establish contact with the nest in the soil from which they originated. However, it is important to examine all materials that have been attacked and damaged during the infestation and to replace or repair where necessary.

Drywood Termites can only be eradicated by fumigation which is a very specialised job. It may be carried out by experts only. Painting the less affected timber with Heptachlor 40wp solution in white spirit can ensure some protection from further infestation. As only limited penetration can be obtained by a single brush application the treatment should be repeated at frequent intervals so as to effect sufficient penetration to destroy the infesting Termites. Treatments must continue until all signs of Termite activity cease. Less troublesome is the use of creams or pastes containing Heptachlor 40wp. They enable considerable penetration of the timber to be effected in the course of single treatment but considerable care should be taken when using them.

All damaged timber that needs replacement should be replaced with treated timber. Timber that has been treated with white Spirit—Heptachlor 40wp Solution should be allowed to dry out for some time before painting.

Having got rid of the infesting termites and having taken precautions to prevent them returning do not conclude that the termites have given up the fight. Keep your eyes open and carry out regular inspections.

32.8 PREPARATION OF HEPTACHLOR 40WP SOLUTION FOR TREATMENT

Add 1 gallon of Heptachlor 40wp in 40 gallons of water and mix well with a stick or stirrer. This will give 0.5% emulsion ready for treatment.

Quantity of Solution Required for 100 Sft Area

a) Monolithic Slab (New)

Perimeter of 130 ft. requires 52 gallons. Overall treatment of 1000 sft. requires 100 gallons of mixture. Minimum total quantity required is 152 gallons of mixture or 4 gallons of Heptachlor 40wp

b) Floating or Suspended Slab (New)

Perimeter of 130 sft. requires 156 gallons. (4 gallons inside and 8 gallons outside per 10 ft. run).
Overall treatment of 1000 sft. requires 100 gallons (1 gallon/10 sft).

Minimum total quantity - 256 gallons (6½ gallons of Heptachlor 40wp - 20 EC).

d) Existing Slab-on-Ground (All Types)

Perimeter of 138 ft. (1 foot from walls) requires 138 gallons per 10 ft. for trenching and 2 gallons per 10 ft. soil between trench and wall)

32.9 PREPARATION OF POISONED CONCRETE AND SAND-CEMENT-MORTAR

To prepare poisoned concrete or sand-cement-mortar, simply use 0.5% Heptachlor 40wp emulsion, as described earlier instead of usual mixing water. There is no effect on the amount of water required, consistency, curing or strength.

If the aggregate or sand is so wet that the amount of added water has to be reduced considerably then add 2 gallons of Heptachlor 40wp in 40 gallons of water.

Sand-Cement-Mortar used for sealing cracks or gaps should be poisoned and should not be stronger than 3 : 1 Sand-Cement by volume.

Preferably it should be plasticised with lime as a 1:1 : 6 Cement-lime-sand mix. The amount of added emulsion should be the minimum required for a workable mix.

32.10 SAFETY MEASURES

1. When using anti termite chemical, keep all children and animals away from the area where treatment is to be carried out.
2. In handling concentrated emulsions or liquid, take care to avoid splashing the liquid on to the skin or clothing. Try to use face shield and PVC gloves if possible.

If accidentally splashed, wash the skin well with soap and water immediately. DO NOT SCRUB. Change clothing if necessary and wash soiled clothing with soap. Eyes affected by splashing should be immediately well washed with water for at least 15 minutes and consult a doctor immediately.
3. Wash well with soap and water after using the chemicals, especially before eating, smoking or drinking. Use clean clothing and PVC foot-wear and change them whenever contaminated.
4. Where the chemical is being used, never eat or drink near by. Either remove all foodstuff away from the place that is being treated or make certain that the chemical does not come in contact with food or drinking water. Never store the chemicals or the emulsions in bottles in such a way that they can be drunk accidentally.
5. After use, wash all equipments including spade, korai, karni etc. and lock up all unused material. All used containers washings from drains or troughs with plenty of water to prevent animals drinking contaminated water.
6. DO NOT suck or blow through a pipe containing the chemical.

WATER SUPPLY AND SEWERAGE SYSTEM**33.1 SCOPE OF WORKS**

This work covers all the operations in connection with pipes, fixtures, equipments and accessories to convey potable water, waste water and other fluid as mentioned in the drawings. All works shall conform to the Bangladesh National Building Code.

33.2 GENERAL REQUIREMENTS

- 33.2.1 Drawings :** The drawing indicates the general arrangement of the plumbing and piping details. However where natural field conditions necessitates a rearrangement, the contractor shall prepare and scrutiny detailed shop drawings of the proposed rearrangement for approval of E/C. Because of the small scale of the drawings, it may not be possible to indicate all offsets, fittings and accessories, which may be required. Therefore the contractor shall carefully examine the drawings and investigate the structural and finished conditions affecting all of his works and shall arrange such work accordingly, furnishing such fittings, traps, valves and accessories as may be required to meet such conditions.
- 33.2.2 Specification :** Materials, Fittings, Fixtures, Equipments required for the work which are not covered by the detailed specification shall be as recommended by the manufacturer or consistent with good practice and approved by the E/C.
- 33.2.3 Cutting and Repairing :** The work shall be carefully laid out in advance and any cutting of construction shall be done only after getting the written permission of the E/C. Cutting shall be carefully done and any damage to the existing buildings, pipings, wirings or equipments as a result of cutting for installation, shall be repaired by skilled worker of the trade involved at no additional expense of the employer.
- 33.2.4 Protection of Fixtures, Materials and Equipments :** Pipe openings shall be closed with caps or plugs during installation. Fixtures and equipments shall be tightly covered and protected against any sorts of injury. At the completion of the work fixtures, materials and equipments shall be thoroughly cleaned and delivered in a condition satisfactory to the E/C.
- 33.2.5 Location of pipes :** On the ground floor, water and soil pipes will generally run under the concrete floor in the appropriate location as indicated in drawings. Pipe Sleeves shall be provided for the crossing of beams, walls etc. pipe location shall not interfere with the reinforcing steel in the beams or floor slab or with the shear concrete in beams or walls. Prior to placing the pipes a detailed shop drawing including its location shall be approved in writing by the E/C.
- 33.2.6 Pipe supports :** Pipe support shall permit some motion between the pipe and support. Pipes shall be adequately supported to prevent sagging. Pipes shall not be rigidly attached to the building as movement between the pipe and its support should be made possible. Approved damping materials should be used in pipe supports to deaden sound.

33.2.6.1 Horizontal pipes : When pipes are laid horizontally or sloping, then it should be supported atleast at every 3.5 m. and at each joints.

33.2.6.2 Vertical pipes : Vertical pipes starting from the ground should be supported on a concrete or brick works. Vertical runs of pipe shall have heavy wrought iron clamps or collars for support, spaced not over 4.5m.

33.2.6.3 Pipe hangers : Horizontal overhead runs of pipe shall be hanged with approved heavy adjustable wrought iron or malleable iron pipe hangers, spaced not over 10 ft. apart.

33.2.7 Gradients : Drain pipes shall be laid according to the following gradients unless other wise specified.

Dia of pipe in mm	Gradient
100	1 in 50
150	1 in 100
225	1 in 200
300	1 in 250
425	1 in 350

33.2.8 Laying of pipes : Pipe shall be laid with bells facing upgrades. Except at closures not less than two lengths of pipe shall be in position ahead of each joint, with packing installed and earth fill tamped alongside the pipe, before the joint is poured. For pressure mains adequate thrust blocks shall be provided. Exposed end of pipes in trenches shall be fully protected with a board or other approved stopper to prevent earth or other substances entering the pipes.

33.2.9 TRENCHING, BEDDING AND BACK FILLING

33.2.9.1 Trenching : Banks of trenches shall be vertical or as directed by the E/C. Trench width must be great enough to provide room to join the pipe sections and install required fittings. Clearance of about 150mm. (6in.) on either side is normally adequate. The trench width must be increased at joints and fittings. An extra depth of 150 mm. (6in.) and extra width of 250mm. (10in.) on either side should be provided for a distance of 900mm. (3ft.) at the joints. Excavated materials shall be deposited at a distance of 450mm. from trench banks. The depth of ground cover shall be at least 0.9m under road way or 0.75m under garden from the top surface of the pipe to the ground surface. The bottom of trench shall be carefully prepared so that the pipe will be bedded well for its entire length on firm surface.

While shoring and dewatering required during excavation, shall be done at the contractors own cost.

The length of excavation in advance for pipe laying shall not be more than 30m, unless other wise directed.

When the depth of trench is more than 1.5m, the sides should be properly sheeted and braced. Contractor shall take all possible measures for the safety of the workers involved in this connection.

33.2.9.2 Bedding : Standard pipe bedding conditions are illustrated in figure.

33.2.9.3 Backfilling : Back filling in the trenches shall be done with approved materials in layers of 150 mm and must be thoroughly compacted. Backfill material should be free of cinders, refuse and large stones.

33.2.10 Specification of Pipes, Fixtures and Fittings

All pipes, fixtures, fittings and setting compounds and jointing materials, shall conform to the specification shown, against their names as follows unless otherwise specified or instructed by the E/C. All samples shall have to be approved by the E/C.

33.2.10.1 Specification for pipes

- (a) Cast iron (water) pipe : ASTM D377
- (b) Galvanized steel pipe : ASTM A53
- (c) Polyvinyl chloride (PVC) pipe : BS 3505 or
- (d) Copper or Copper alloy pipe : alloy pipe : ASTM B42, ASTM B302
- (e) Concrete pipe : ASTM C14M, ASTM C76M
- (f) Vitrified clay pipe : ASTM C4, ASTM C700

33.2.10.2 Specification for Pipe Fittings

- (a) Cast iron pipe : ASTM C564 ASME B164, ASME B16.12
- (b) Malleable iron fittings : ASME B16.3
- (c) Plumbing fixtures and drains : Federal specification WW-P-541
or WW-P-542, as application.
- (d) Nipples (same materials) : Federal specification (malleable iron (Galvanized))
 - a) 50 mm and below WW-P-531 type B
 - b) 65 mm and up WW-P-406

33.2.10.3 Specification for pipe setting compound and jointing materials.

- (a) Cast iron pipe fittings: ASTM C564 Federal specification HH-C-536
- (b) Galvanized steel pipe fittings : ASME B1.201, Federal specification HH-C-116
- (c) PVC plastic pipe fittings : ASTM D2846, ASTM D3139, ASTM F493, ASME B1.20.1 HH-C-116
- (d) Concrete pipe fittings : ASTM C443
- (e) Twisted jute packing : Federal specification HH-P-117 type II
- (f) Vitrified clay pipe fitting : ASTM C425

33.2.11 Pipe Installation

- (a) Air chamber for water hammer control shall be provided on cold water supplies at each faucet, control valve, flush which is not definitely shown on the drawings shall consist of 250mm length of pipe of same diameter as the branch supply pipe, fitted with a cap.
- (b) No plumbing systems or part there of, shall be covered unless it has been inspected and approved. All G.I. Pipes less than 40mm dia when embedded in 125mm thick walls shall be located in the mid thickness of wall. In brick walls pipes shall be supported by concrete at least 40 mm thick all around.
- (c) When pipes are to be embedded in wall with insufficient cover (less than 40 mm) or if it is to be exposed, it shall be supported by clamps and nails/nuts and bolts according to approved designs/methods. The distance between supports shall not exceed 1.0m and anchor bolts shall not be less than 10mm "U" pipes.
- (d) Pipe shall be cut accurately to measurement and shall be worked into place without springing or forcing. Care must be taken that structural members of the building is not weakened.
- (e) Service pipe valves and fittings shall be kept at sufficient distance from other works and services to permit not less than 12mm between finished covering of the different services. Changes in pipe diameter shall be made by using reducers. The use of bushing will not be allowed.
- (f) Branch pipe from service lines may be taken over and under other pipes by using proper crossover fittings as per drawing or or as per instruction of E/C.

33.3 Water Pipe, Fittings and Connections

33.3.1 Piping and Fittings

Water pipes shall be galvanized iron suitable for threaded jointing and complying with specification ASTM A53.

Pipe work includes supply, fitting and fixing complete with bends, tees, unions, reducers as per drawing or instruction of E/C. Sample of pipes and fittings to be used in the work shall be supplied by the contractor for approval of E/C.

All water pipe fittings shall be similar in every respect to the pipe.

33.3.2 Installation

- (a) A gate valve and drain valve on the service line shall be installed inside the building. The piping shall be extended to all fixtures, outlet and equipment from the gate valve. The cold water system shall be installed with a fall toward the shut off valve. Supply line taken from pressure or gravity tanks shall be valved (approved type) at or near its sources and an interior stop and waste valve or cock shall be provided for each outlet or group of outlets. Stop and waste cocks shall be accessible and of such size and so installed as to permit complete drainage of the entire water supply system they serve.
- (b) A capped tee shall be installed below the shut off valve on each water service riser.
- (c) Mains, Branches and Runouts piping shall be installed as indicated in the drawings. Pipe should be cut accurately to measurements established at the building by the contractor and shall be worked into place without springing or forcing. Care shall be taken not to weaken the structural portion of the building. Piping above ground shall run parallel with the lines of the building unless otherwise shown or noted on the drawing.
- (d) Service pipes, valves and fittings shall be kept at sufficient distance from other works and other services to permit not less than 12mm between finished covering of the different services. No water piping shall be buried in floor unless specifically indicated on drawings.
- (e) All water pipes shall be so graded or pitched that the entire system or parts thereof can be drained and the formation of traps or sags shall be avoided where possible, but where they occur, each sag, trap or invert shall have provision for complete drainage.
- (f) There shall be no cross connection between potable water distribution and nonpotable water distribution or water disposal systems.

34.3.2 Disinfection : The following procedure may be adopted to disinfect the plumbing system :

- a) The water supply system or storage tank shall be flushed with potable water until clean water appears at the outlets.
- b) The system or part thereof which requires disinfection shall be filled up with chlorinated water containing 50mg/L. of chlorine for 24 hours or for 3 hours with a chlorinated water of chlorine concentration of 200mg/L.
- c) After the period disinfection, the system shall be flushed with potable water until the chlorine is completely removed from the water in the system.
- d) The above procedure shall be repeated until the bacteriological examination shows presence of no water contamination within the system.

33.3.4 Jointing : Threaded joints of galvanized iron pipe must conform the requirements of ASME B1.20.1. After cutting and before threading, pipe shall be reamed and shall have burrs removed. Screw joints shall be made with hemp yarn soaked in China lacquer or with an approved graphite compound applied to male threads only. Threads shall be fully cut and not more than three threads on the pipe shall remain exposed. Threads at the end of G.I. pipes and inside the socket shall be examined and cleaned. Damaged threads shall be cut with sharp dies. Before installation threads shall be coated with approved jointing compound (Graphite and oil mix). The pipe shall be fitted into the socket tightly threaded joints to stop or prevent leakage Unions shall be provided where required for disconnections.

33.3.5 Alignment and Slopes : Pipes shall be laid as straight as possible and shall be free from upward bends and downward dips. Water supply pipes shall be sloped at not less than about 1/4" inch per ft. to a point of drainage where a valve is placed.

33.3.6 Tests of Water Supply Pipes

Immediately after the pipes are laid jointed and flushed clean but not covered, all pipes shall be inspected and tested for alignment, leakage etc. Testing equipments and pumps shall be arranged by the contractor.

(a) **Water test :** The entire opening of pipe system to be tested are closed.

A pressure of not less than 500 KPa water pressure is developed in the pipes by attaching a hand force pump to the plumbing systems. The force pump is equipped with a pressure gauge. After the required pressure is attained the pump is stopped. Piping system shall be tested under this pressure for at least 2 hours and at 340 kpa pressure for 24 hours.

(b) **Air Test :** A pressure of not less than 5 psi shall be applied with a force pump and maintained at least 15 minutes. The fall of pressure in the pressure gauge attached to the pipes, will indicate absence of any leakage, in the system.

(c) **Testing of hot water system :** The entire hot water system shall be tested for the maximum rated temperature and pressure of hot water storage system. The system pressure. All safety devices shall be tested for their proper operation.

33.4 SOIL, WASTE WATER, RAINWATER AND VENT PIPING

(a) All exposed piping for soil, waste, and rainwater drainage and venting, shall be of heavy duty cast iron, conforming to ASTM A74 (unless modified) with spigot and socket joints having projecting ears. All fittings shall be similar in every respect to the pipe. The pipe shall be coated with atleast 2 coats of epoxy paints.

(b) Out side building, connection sewer pipes : Sewer lines 1.5m beyond the building line shall be reinforced centrifugally spun concrete pipe having 20 mil. coaltar epoxy lined. P.V.C. pipe can also be used if instructed.

33.4.1 Installation

(a) **Handling :** Pipes and accessories shall be handled in such a manner as to insure delivery to the point of installation in sound, undamaged condition. Pipe coating should not be injured

Cutting of Pipe :

(b) Cutting of pipe shall be done in workmanlike manner without damaging the pipe.

(c) **Laying and fixing :** Before installation pipes should be detected for cracks by tapping with light hammer. Deflection of pipe from straight line or grade shall not exceed 6/D inches per linear foot of pipe for pipes not more than 350 mm dia, wher D represents nominal diameter of pipe. If alignment requires deflection in excess of this limitations, special bends or a sufficient number of shorter length of pipes shall be furnished to provide angular deflections within the limit set forth.

33.4.2 Pipe Fittings

(a) **Change in size of soil, vent, waste and rainwater down pipes** shall be done with reducing fittings or recessed reducers. Changes in directions shall be done with the use of appropriate Wyes, Tees, Elbows, Bends etc. Sanitary tee shall be used on vertical stacks and where the changes is required from the horizontal to vertical direction.

(b) **Clean outs :** Clean outs shall be of the same sizes as the pipe is, except the clean out plugs larger than 4 inches will not be required.

(c) **Test tees :** Test tees with cast iron cleaned plugs shall be installed at the foot of all soil, waste and rainwater stacks.

(d) **Traps :** Each fixture and piece of equipment requiring connections to the drainage system shall be equipped with a trap. Traps installed on threaded pipes shall be recess drainage pattern.

- (e) **Sleeves :** Pipe sleeves shall be 26 gauge prime and painted metal, properly, secured in place with a space of approximately 6 mm between the sleeve and pipe passing through concrete or masonry wall and floors above grade. Pipe sleeves in concrete beams or bearing walls shall be wrought or steel pipe. Where piping is insulated, the insulation shall be continuous through the pipe sleeves with a clearance of approximately 6mm between the outside of passing pipe covering and the pipe sleeve. The space between the sleeves and the pipe shall be made water tight by inserting a packed oakum gasket, and filling the remaining space with pig lead and thoroughly caulking.

33.4.3 Jointing Pipes

33.4.3.1 Cast Iron Pipe

- (a) **Bell and spigot joints :** Before jointing such pipes, all sorts of lumps, blisters and excess coating materials shall be removed from the bell and spigot ends. Oil and grease if there any shall be removed. The out side of the spigot and inside of the bell shall be wire brushed and wiped clean and dry. Joint packing in the joints shall be carefully placed and should be caulked tightly to a uniform thickness. No loose or froayed ends of fibres shall be protruded into the space to be filled with joint filler. Each joint shall be carefully inspected and checked for proper depth before the joint runner is attached. If the bell end have approved inside contour then it may be packed with rubber ring gasket without caulking.
- (b) **Lead joint :** The spigot end of the pipe should be properly inserted in the bell of the other pipe. Twister or spun oakum is then caulked into the annular space or socket. The oakum must be thoroughly compressed to make a solid bed for lead sufficient amount of melt lead is then poured into the remaining space of the socket. The poured lead is then to be caulked while the joint is hot and caulking is to be finished when the joint becomes cool.

(d) **Amount of lead to be used for jointing :**

Size of pipes	2"	4"	6"
Lead (lbs/joint)	1.5	3	4.5

Specification : for jointing different pipe used in soil and wastewater drainage

Cast iron bell and spigot - Galvanized	ASTM C564
Concrete (non pressure)	ASTM C443
PVC	ASME B1.20-1
Vitrified Clay pipe	ASTM C425

33.4.3.2 PVC pipe

The inside of the socket and outside of the spigot upto the depth of entry, must be roughened by using sand paper or emery paper. The roughened portion must be kept clean by keeping free from dirt, grease and any swarf from the mating surfaces. Without delay just after cleaning an even, unbroken layer of solvent cement of approved quality shall be applied outside the spigot and inside of the socket upto the depth of entry. Then the pipe spigot end of the pipe would be inserted into the socket until the bottom of socket is reached. The jointed pipes must be held in position for a few second and excess cementing material should be wiped off.

33.4.3.3 Concrete Pipe : Joints

A Cement mortar joint : A closely twisted hemp and/or oakum gasket in one piece of sufficient length to pass around the pipe and lap at the top, shall be thoroughly saturated in cement mortar of equal parts of cement and sand. The gasket shall be laid in the bell for the lower third of the circumference of the joint and covered with mortar. The spigot end being properly cleaned shall be inserted into the bell after which sufficient amount of mortar shall be inserted into the annular space around the entire circumference of the pipe and solidly rammed into the joint, the mortar previously placed being driven ahead of the gasket. The remainder of the joint shall then be completely filled with mortar and bevelled off at an angle of 45° with the outside of the pipe.

**EARTHQUAKE RESISTANT
MASONRY STRUCTURE****34.1 Introduction**

The phenomenon of earthquake is as old as the earth itself and is likely to continue as long as the planet exists. Historical records indicate that most of the losses due to earthquake have occurred due to collapse of masonry structure. Recent frequent earthquakes and the presence of highly seismic zones in India near the North-Eastern side of Bangladesh has lead us to the fact that Bangladesh is situated in a seismically active zone. As such safety of masonry structures from the fury of earthquake is of highest priority. To overcome this, very simple modifications are suggested in this chapter, which could be incorporated with little additional cost to make the structure earthquake resistant.

34.2 Basic Considerations

From the safety point of view, the safety of human lives is the primary concern and the functioning of the building has lower priority except those buildings required for emergency such as buildings for hospitals, operation theatre, telephone, telegraph, fire fisting and the like. The safety aims would, therefore, be met, if a building is designed and constructed in such a way that even in the event of the probable maximum intensity of the earthquake,

- i) an ordinary building should not suffer total or partial collapse;
- ii) it should not suffer such irreparable damage which would require demolishing and rebuilding;
- iii) it may sustain such damages which could be repaired quickly and the building put back to its usual functioning;
- iv) the damage to an important building should even be less so that the functioning of the activities during post emergency period may continue unhampered and the community building such as schools, assembly halls etc. may be used as temporary shelters for the adversely affected people.

34.3 Factors affecting damages in buildings.

- a) **Building Configuration:** An important factor is symmetry and regularity. A building shaped like a box such as rectangular both in plan and elevation, is inherently stronger than one that is L-shaped or U-shaped
- b) **Opening size:** Openings in walls tend to weaken the wall. Openings should be small. For large openings special provision to be made.

- c) **Rigidity distribution:** Changes in the structural system from one floor to next should be avoided. Columns and shear walls should run continuously from foundation to roof without interruption.
- d) **Ductility :** Ability of building to bend, sway and deform by large amount without collapse should be provided by adding steel at selected places of the building.
- e) **Foundation :** Certain type of foundation, say brick foundation, is more susceptible to damages than R.C.C. foundation. Isolated footing in one building on different types of soils is subjected to different settlement. Mixed type of foundation within same building may also lead to differential settlement.
- f) **Construction quality :** Poor construction, sub- standard materials, poor workmanship e.g. inadequate skill in bonding etc. may lead to failure in earthquake.
- g) **Site conditions :** Structures built on firm soils frequently fair better than buildings on soft soil.

34.1 General concept of earthquake resistant design

- a) **Plan of the building :**
 - i) **Symmetry :** The building as a whole or its various blocks should be kept symmetrical about both the axes. Asymmetry tends to torsion during earthquake and is dangerous. Symmetry is also desirable in the placing and size of the door and window openings as far as possible. (Fig. 34.1)

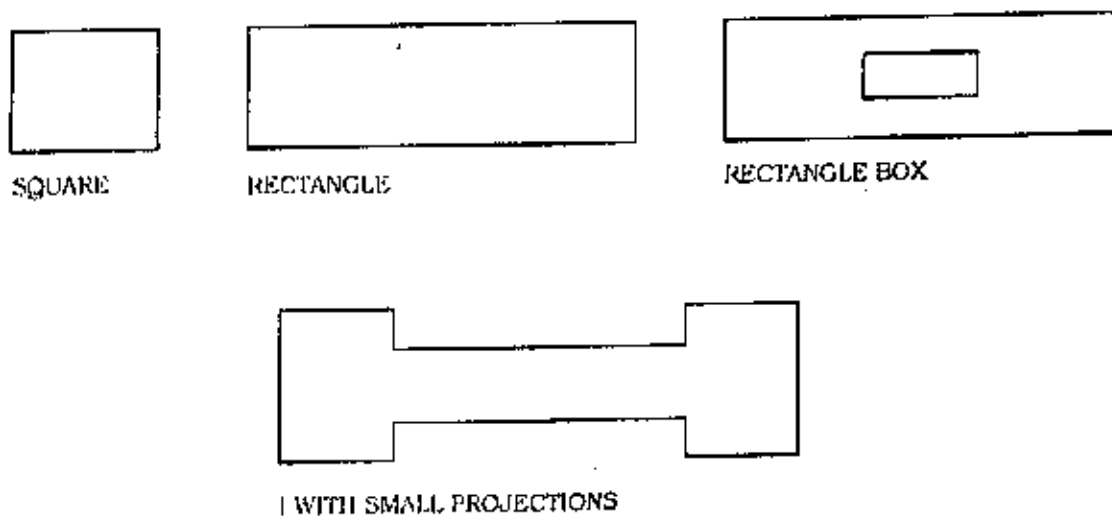


Fig. 34.1 Symmetrical desirable plans

- ii) **Regularity :** Simple regular shapes behave better in an earthquake than shapes with many projections. Torsional effects of ground motion are pronounced in long narrow rectangular blocks. Therefore, it is desirable to restrict the length of a block to three times its width. If longer lengths are required, two separate blocks with sufficient separation in-between should be provided.

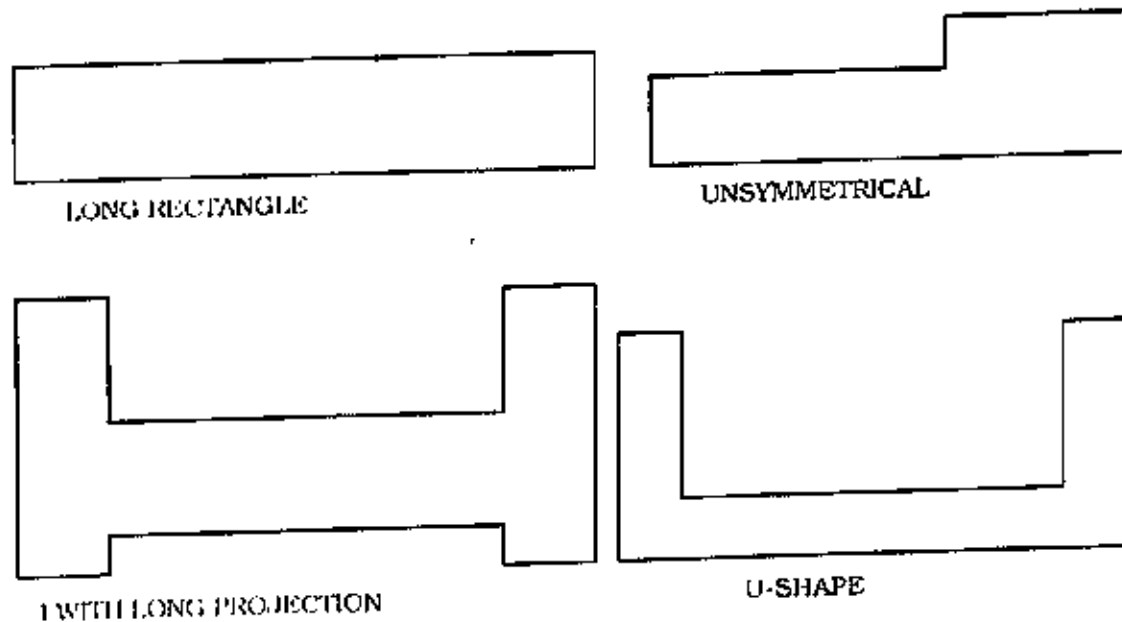


Fig. 34.2 Long or unsymmetrical undesirable plans

- iii) **Separation of blocks:** Separation of large building into several blocks may be required so as to attain symmetry and regularity of each block. The separation section may be treated just like an expansion joint, or it may be filled or covered with weak materials, which would easily crush and crumble during earthquake shaking.

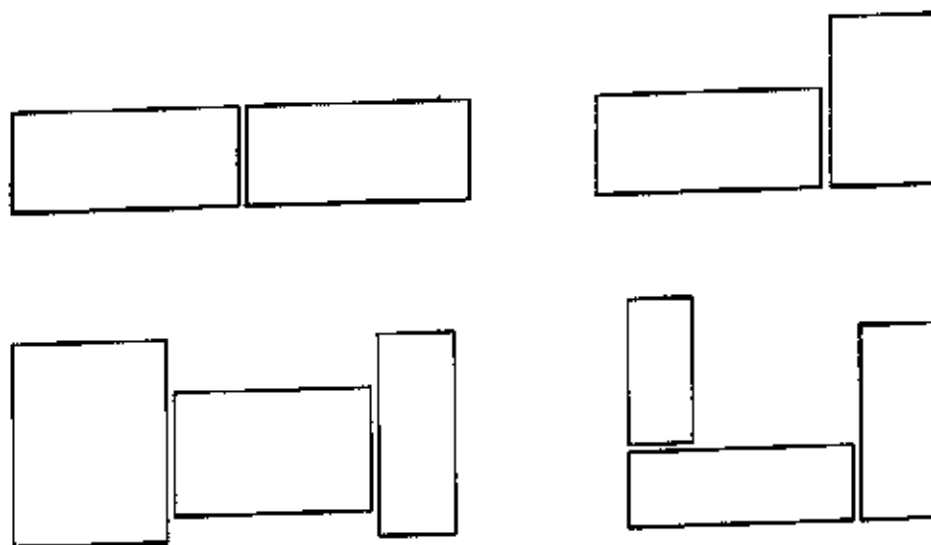


Fig. 34.3 Use of separation for improving plans

- iv) **Simplicity:** Ornamentation involving large cornice, vertical or horizontal cantilever projections, face stones and the like are dangerous and undesirable from a seismic view point. Simplicity is the best approach.

When ornamentation is insisted upon, it must be reinforced with steel which should be properly embedded or tied into the main structure of the building.

- v) **Enclosed Area** : Small buildings with properly interconnected walls acts like a box and behave better against earthquake.

34.5 Structural Design

- a) **Ductility** : Ductility is the most desirable quality for good earthquake performance and can be incorporated to some extent in otherwise brittle masonry construction by introducing steel reinforcement at critical sections.
- b) **Deformability** : Deformability is a less formal term referring to the ability of the structure to displace or deform substantially without collapse. Besides internally relying ductility of materials & components, deformability requires that structure be well proportioned, regular and well tied together.
- c) **Damageability** : Damageability is also a desirable quality of construction and refers to the ability of a structure to undergo substantial damage without partial or total collapse.

A key to good damageability is redundancy or provision of several columns or walls supporting excessively large portion of a building. A key to good damageability is always to ask the question :

"If this beam, column, wall etc. fails what is the consequence?"

If the consequence is the total collapse of the building additional supports or alternate structural layout should be examined or additional factor of safety be furnished for such vertical members.

34.6 Requirements of structural safety

The following main requirements of structural safety of building should be considered :

- a) A free standing wall must be designed to be safe as a vertical cantilever. All partitions must be held on the sides as well as top.
- b) Horizontal reinforcement in walls is required for transferring their inertia load horizontally to the shear walls.
- c) The walls must be effectively tied together to avoid separation at vertical joints due to ground shaking.
- d) Shear walls must be present along both the axes of the buildings.

34.6.1 Foundation

The depth of footing in the soil should go below the level of shrinkage cracks in clayey soils. For choosing the type of footing from earthquake point of view the soil may be grouped into firm & soft soil, avoiding the weak soil unless compacted and brought to soft or firm condition.

Continuous reinforced concrete footings are considered to be most effective from earthquake consideration as well as to avoid differential settlement under normal vertical loads.

34.7 Causes of Damage in masonry buildings

The following are the main weaknesses in the materials and unreinforced masonry construction :

- Heavy weight and very stiff buildings attracting large seismic inertia force
- Very low tensile strength, particularly with poor mortar

- Low shear strength, particularly with weak mortar
- Weak connection between wall & wall
- Weak connection between wall & roof
- Stress concentration at corners of windows & doors
- Overall unsymmetry in plan and elevation of building
- Unsymmetry due to imbalance in the sizes and positions of openings in walls
- Defects in construction such as use of sub-standard materials, unfilled joints between bricks, not plumb walls, improper bonding between walls at right angles.

34.8 General construction aspects

34.8.1 Mortar :

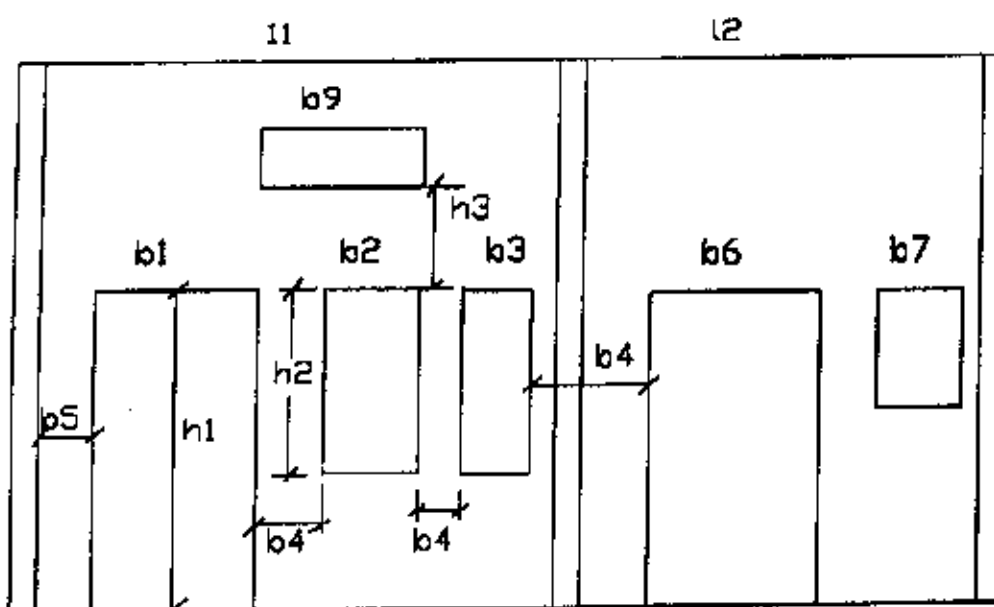
Since tensile and shear strength are important for seismic resistance of masonry walls, a mortar mix of proportion 1:6 by volume or equivalent in strength should be the minimum.

34.8.2 Wall enclosure :

In load bearing wall construction the wall thickness 't' should not be less than 190mm, wall height not more than 20t, wall length between cross walls not more than 40t. If longer rooms are required, the wall thickness should be increased or additional safety provisions should be made.

34.8.3 Opening in walls:

- Openings should be small in size and as far as possible centrally located.



Notes : $b_1 + b_2 + b_3 < 0.5h_1$ for 1-storey, $0.42h_1$ for 2-storey, $0.33h_1$ for 3-storey
 $b_6 + b_7 < 0.5h_2$ for 1-storey, $0.42h_2$ for 2-storey $0.33h_2$ for 3-storey
 $b_4 > 0.5h_2$ but not less than 60cm
 $b_5 > 0.25h_1$ but not less than 60cm
 $h_3 > 60\text{cm}$ or $0.5(b_2 \text{ or } b_9 \text{ whichever is more})$

Fig. 34.4 Recommendation regarding openings in walls

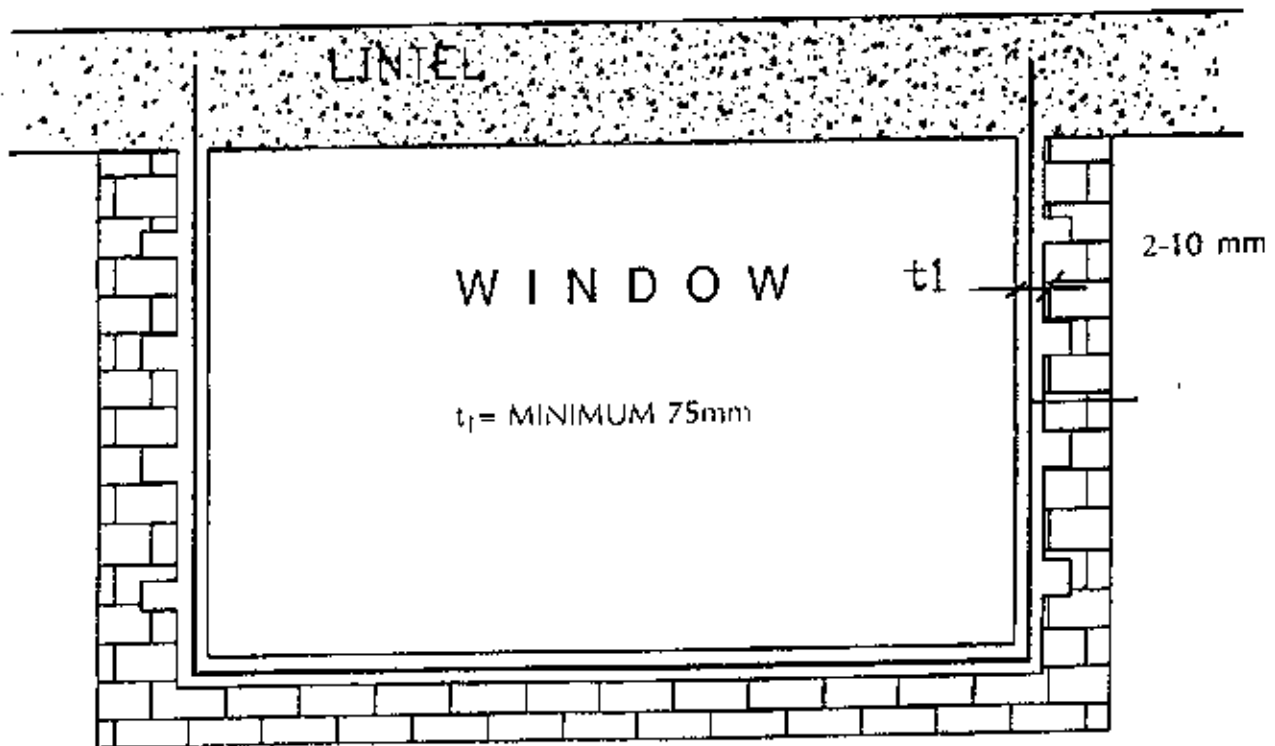


Fig. 34.5 Strengthening of masonry around openings

- The total length of the openings not to exceed 50% of the length of the wall between consecutive cross walls in single story, 42% in 2- story and 33% in 3- story buildings
- The horizontal distance (Pier width) between two consecutive openings to be not less than $1/2$ of the height of the shorter opening but not less than 60 cm.
- The vertical distance from an opening to another opening directly above it not less than 60 cm or less than $1/2$ of the width of the smaller opening.
- When the openings do not comply with requirements stated above, they should either be boxed in reinforced concrete around or reinforcing bars provided at the jams through masonry

34.8.4 Masonry bond :

For achieving full strength of masonry the usual bonds specified for masonry should be followed so that vertical joints are broken properly from course to course.

34.8.5 Horizontal reinforcement in walls :

Horizontal reinforcement of walls is required for imparting to them horizontal bending strength and for tying the perpendicular walls together.

The following reinforcing arrangements are necessary :

- a) Plinth band : This band is very useful specially when soil is soft or uneven. It will also serve as damp proof course.
- b) Lintel band : This is the most important band and will incorporate in itself all door and window lintels, the reinforcement of which should be extra to the lintel band steel. It must be provided in all stories of building.
- c) Roof band : The band will be required at eave level of trussed roof and it is not required in case of R.C.C. roofs.

- d) Gable band: Masonry gable ends must have the triangular portion of masonry enclosed in a band, the horizontal part will be continuous with eave level band on horizontal walls.

34.8.6 Size and reinforcement of bands

- Two (or four) longitudinal bars with links or stirrups embedded in 75mm (150mm) thick concrete

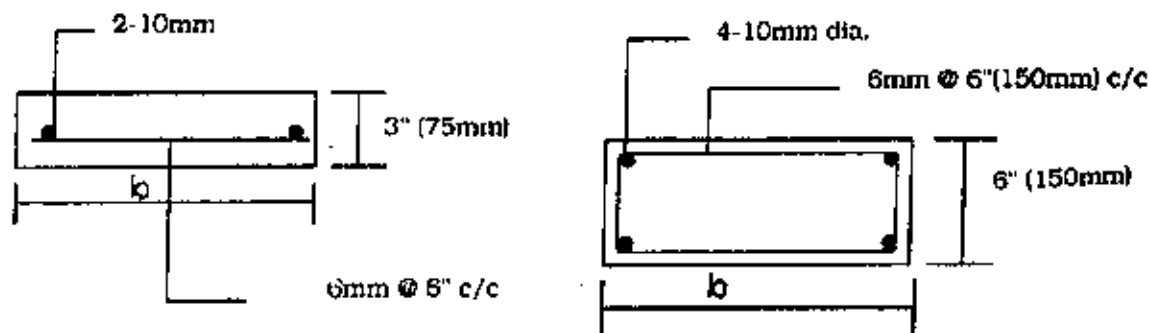


Fig. 34.6 Cross section of R.C.C. bands for 2 bars and 4 bars

- for 10" (250 mm) walls, 4- 10mm bars with 6 mm stirrups 150mm c/c
- the vertical thickness of R.C.C band may be kept minimum 75 mm where 2 longitudinal bars are specified and 150mm where 4- longitudinal bars are specified.
- the steel bars are located closes to the wall faces with minimum 25mm cover and full continuity is provided at corners and junctions.
- the thickness of band may be made equal to or multiple of masonry units and its width should equal the thickness of walls.
- the reinforcement and thickness of band over door and window openings should be as per design.

34.9 Dowels at corners and junctions

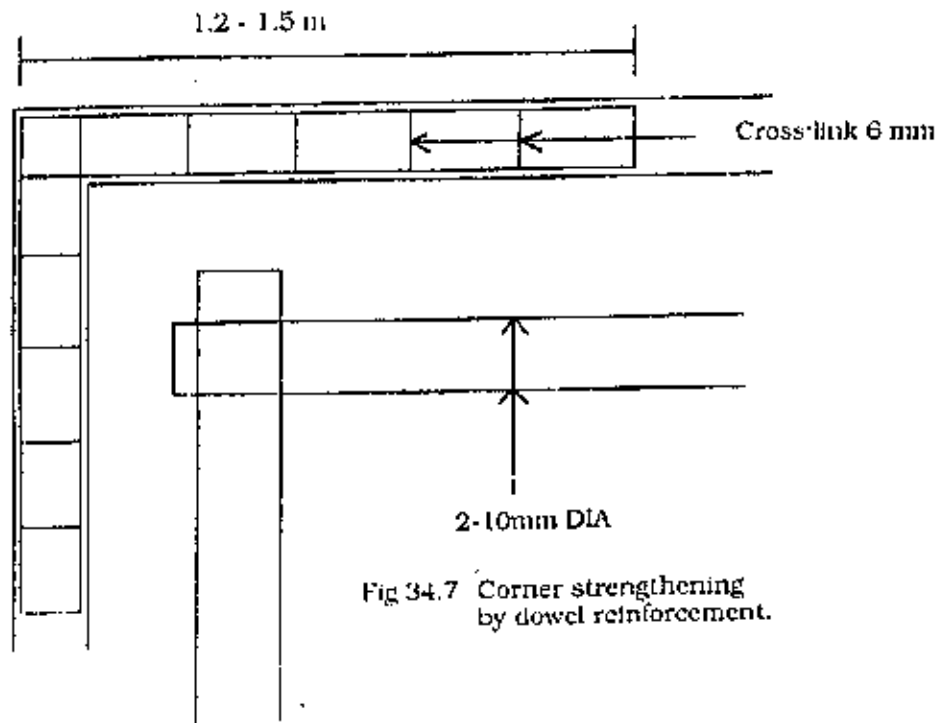
As a supplement to the bands described above, steel dowel bars may be used at corners & T-junctions to integrate the box action of walls. Dowels are placed at every 4th course or at about 50 cm intervals and taken into walls to sufficient length so as to provide the full bond strength. Dowel bars may be replaced by wire fabrics.

34.10 Vertical reinforcement in walls

- Critical sections for providing vertical steel are the jambs of openings and corners of walls.
- Steel bars are to be installed at critical sections right from foundation and covered with cement concrete in cavity made around them during masonry construction.
- Concrete mix proportion shall be 1:2:4 by volumes or richer.
- Install embedded R.C.C. Column of size 10"x 10" for 10" wall with 4- 10mm vertical bars & 6mm stirrups 10" c/c at selected exterior corners of the building.

34.11 Seismic Zoning of Bangladesh & minimum requirements

Based on the severity of the probable intensity of the seismic ground motion and damages, Bangladesh has been divided into three seismic Zones, i.e Zone-1, Zone-2, Zone-3, with Zone-3 being the most severe.



As Zone-1 has least possibility of earthquake, BNBC 93 has not suggested any additional provisions for this zone.

All masonry structure constructed in Zone-2 and Zone-3 shall be designed in accordance with the provisions of BNBC 93.

For Zone-2 and Zone-3 wall bands shall be provided at plinth and lintel level. In addition vertical and horizontal reinforcements as provided in BNBC and discussed in earlier articles shall be provided for brick masonry structure.

In addition, embedded corner columns as discussed previously at selected corners shall be provided for Zone-2 and Zone-3

PART-III
SPECIFICATION, DESCRIPTION OF E/M
INSTALLATION WORKS

TERMINOLOGY

Some Terms are explained as follows :

- a) **Light** : any radiation capable of causing a visual sensation directly i.e. visible radiation.
- b) **Light output ratio** of a luminaire, is the ratio of the light out put of the luminaire, measured under specified practical condition, to the sum of the individual light out puts of the lamps operating outside the luminaire under specified conditions.
- c) **Luminaire** : complete lighting apparatus consisting of a lamp or lamps together with the parts designed to distribute, filter or transform the light, to fix and project the lamps and to connect them to the supply ckt.
- d) **Brightness (of luminosity)** : attribute of visual sensation according to which an area appears to emit or reflect more or less light. It is the luminous intensity of any surface in a given direction per unit of projected area of the surface, as viewed from that direction.
- e) **Colour** : aspect of visual perception by which an observer may distinguish between two fields of view of the same size, shape and structure, as may be caused by differences in the spectral composition of the radiation concerned.
- f) **Colour appearance** : general expression for the colour impression received when looking at a light source. Lamps are usually divided into three groups according to their colour appearance; warm, intermediate and cool. It is one of the two factors characterizing the colour qualities of a lamp.
- g) **Colour rendering** : general expression for the effect of an illuminant on the colour appearance of objects inconspicuous or sub-conscious comparison with their colour appearance under a reference illuminant. colour rendering index of a light source is a measure of the degree to which the psycho-physical colours of objects illuminated by the source, conform to those of the same objects illuminated by a reference lamp, under same specified conditions. The higher the index (Ra) the better the colour rendering property.
- h) **Contrast** : subjective assessment of the difference in appearance of two parts of a field of view seen simultaneously or successively.
- i) **Glare** : condition of vision in which there is discomfort, or a reduction in the ability to see significant objects, or both due to an unsuitable distribution or range of illuminance or to extreme contrasts in space or time.
- j) **Illuminance** : the quantity of light or luminous flux falling on unit area of a surface. Unit: lux, lx.
- k) **Illumination** : the application of visible radiation to an object.
- l) **In candescence** : emission of visible radiation by thermal excitation.
- m) **Incandescent (electric) lamp** : lamp in which light is produced by means of an element heated to incandescence by the passage of electric current.
- n) **Fluorescence** : photoluminescence that persists for an extremely short time after excitation.
- o) **Fluorescent lamp** : discharge lamp in which most of the light is emitted by a layer of fluorescent material excited by the ultraviolet radiation from the discharge.
- p) **Lumen** : the luminous flux emitted within unit solid angle (one steradian) by a point source having a uniform intensity of one Candela.
- q) **Luminance (at a point)** : the ratio of the luminous intensity in a given direction of an infinitesimal element of the surface containing the point under consideration to the orthogonally projected area of the element on a plane perpendicular to the given direction. It is proportional to the product of the illuminance and the surface reflectance, the latter being the ratio of the reflected luminous flux to the incidental luminous flux.

- r) **Luminous flux (Q)** : the quantity derived from radiant flux which express its capacity to produce visual sensation evaluated according to the values of relative luminous effectency for the light adapted eye. Unit: lumen,lm.
- s) **Luminous intensity distribution** : distribution of the luminous intensities of a lamp or luminaire in all spatial directions.
- t) **Maintenance factor** : ratio of the average illuminance on the working plane after a specified period of the use of a lighting installation to the average illuminance obtained under the same conditions for the same lighting installation when new.
- u) **Reflection factor** : ratio of light reflected from a surface to the total light falling on the surface. The reflection factor varies with the roughness of the surface as well as the darkness of the colour.
- v) **Utilization factor** : ratio of the flux received on the working plane to the sum on the fluxes from all the lamps in the interior.
- w) **Working plane** : A horizontal plane at a level at which work will normally be done.

CIRCUIT : An assembly of electrical equipment supplied from the same origin and protected against overcurrent by some protective device.

CIRCUIT BREAKER : A device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent, without in jury to itself when properly applied within its rating.

CIRCUIT, FINAL, SUB : An outgoing circuit connected to one way of a distribution fuse board and intended to supply electrical energy, at one of more points, to current-using appliances without the intervention of a further distribution fuse board other than a one way board. It includes all branches and extensions derived from that particular way in the distribution fuse board.

CORD, FLEXIBLE : A flexible cable having conductor of small crosssectional area. Two flexible cords twisted together are known twin flexible cord.

CUTOUT : Any appliance for automatically interrupting the transmission of energy through a conductor when the current rises above some pre-determined value, for example, fusible cut-out.

DEMAND FACTOR :The ratio of the maximum demand of a system, or part of a system to the total connected load of the system or the part of the system under consideration

DUCT : A closed passage way formed underground or in a structure and intended to receive one or more cables which may be drawn in.

EARTH : The conductive mass of the earth, whose electric potential at any point is conventionally taken as Zero.

EARTH CONTINUITY CONDUCTOR : The conductor, including any clamp, connecting to the earthing lead or to each other, those parts of an installation which are required to be earthed. It may be in whole or in part the metal conduit or the metal sheath or armour of the cables, or the special continuity conductor of a cable or flexible cord incorporating such a conductor

EARTH ELECTRODE : A metal plate, pipe or other conductor electrically connected to the general mass of the earth.

EARTHING LEAD : THE final conductor by which the connection to the earth electrode is made..

FITTING, LIGHTING : A device for supporting or containing a lamp or lamps(for example, fluorescent or incandescent) together with any holder, shade, or reflector, for example a bracket, a pendant with ceiling rose, or a portable unit.

FUSE : a device that, by the fusion of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted when the current through it exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.

INSULATION : Suitable non-conducting material, enclosing surrounding or supporting a conductor.

LIVE (or ALIVE) : Electrically charged so as to have a potential different from that of earth

OVERCURRENT : A current exceeding the rated current. For conductors the rated value is the nominal current carrying capacity.

PLUG : A device carrying metallic contacts in the form of pins, intended for engagement with corresponding socket contacts and arranged for attachment to a flexible cord or cable.

POINT (in wiring) : A termination of the fixed wiring intended for the connection of current using equipment.

SERVICE : The conductors and equipment required for delivering energy from the electric supply system to the premises served.

SWITCH : A manually operated device for closing and opening or for changing the connection of a circuit.

SWITCHBOARD : An assemblage of switchgear with or without instruments; the term, however, does not apply to a group of local switches on a final sub-circuit where each switch has its own insulating base.

SWITCHGEAR : Main switches, cutouts or fuses, conductors and other apparatus in connection therewith, used for the purpose of controlling or protecting electrical circuits or machines or other current-using appliances.

LIGHTING

1.1 VISIBLE LIGHT

Light is electromagnetic radiation of a wavelength to which eyes are sensitive. Fig. shows the ether spectrum, it would be seen that this radiation has wave length range of 380m μ to 780m μ (millimicrons), bounded at one end by infrared radiation of 780m μ to 10,000m μ wave length and ultra-violet radiation of 10m μ to 380m μ wave length at the other end.

The visible light spectrum comprises of a number of different wave lengths, each of which is capable of creating a different colour impression by itself see Figure However, the eyes are in capable of distinguishing the different wave-lengths as separate colours, all of which together appear as white. The colour associated with the different wave length ranges is also indicated in Table-below.

Table - 1

Wave length in m μ	Colour impression
380-420	Violet
420-495	Blue
495-566	Green
566-589	Yellow
589-627	Orange
627-780	Red

Note. The units used for wave length in lighting are the micron, millimicron and angstrom.

1 μ = (micron) = .001mm. = 10^3 mm.

1m μ = (millimicron) = .000001 = 10^6 mm.

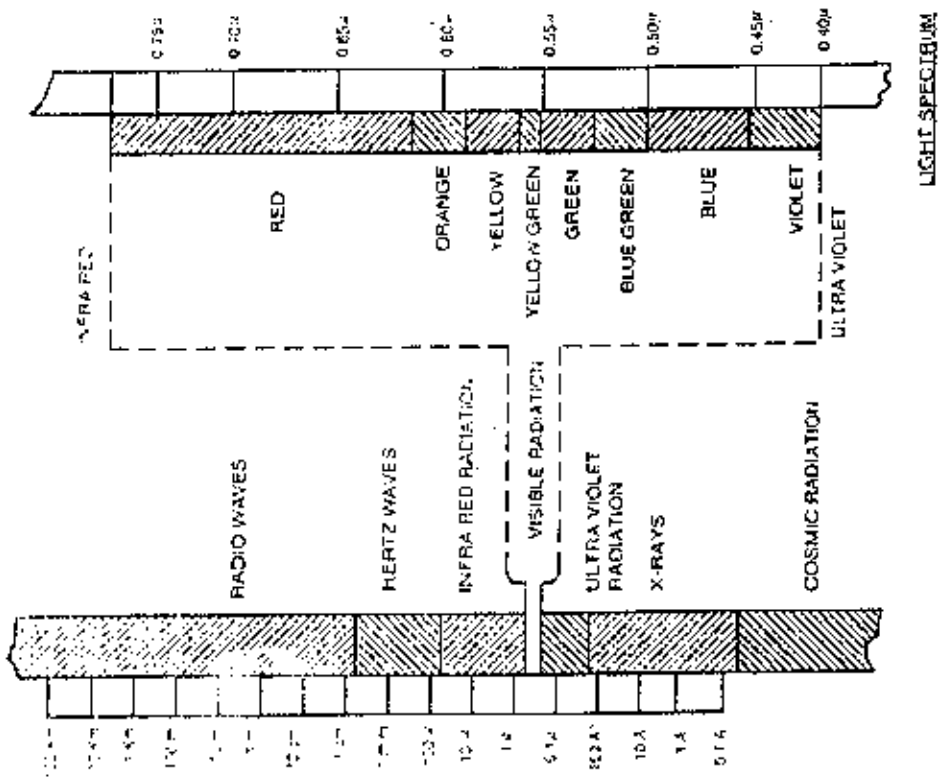
1 Å = (Angstrom) = .0000001mm. 10^7 mm.

The different wave lengths do not produce light impression of the same intensity. The yellow green radiation of 555 m μ wave length creates the strongest impression. Red and violet radiations produce much weaker impressions. The relative sensitivity of different wave lengths is shown in Fig.

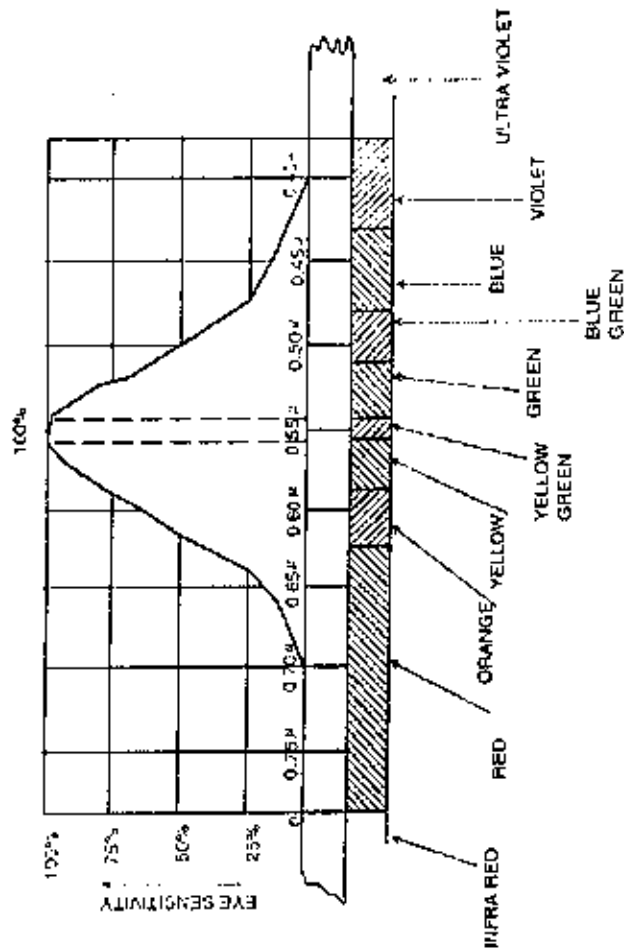
1.2 ILLUMINATION.

1.2.1 Principle of lighting : The essential features of an efficient lighting system are:

- Adequate illumination of the working surface
- Prevention of glare,
- Avoidance of shadows, and
- Ease of maintenance.



THE ETHER SPECTRUM



VISIBLE LIGHT SPECTRUM AND EYE SENSITIVITY

FIG. 1

The basic requirements for building lighting are that adequate light of the right quality is provided and that proper attention is given to the appearance and artistic features of the lighting fixtures and the effects they produce.

Design considerations : The level, quality and design of the lighting in an interior in which work of a visually exacting nature has to be carried out should be based on the requirements of:

- Visual performance
- Visual comfort and pleasantness
- Energy and cost effectiveness

Visual performance is the term used to describe both the speed at which the eyes function and the accuracy with which a visual task can be carried out.

The standard of visual performance for the perception of an object rises with increasing illuminance or luminance up to certain level. Other factors that influence performance are:

- size of the visual task and its distance from the eye (i.e apparent size)
- contrasts in colour and luminance.

The degree of visual satisfaction in terms of comfort and pleasantness created by the lighting is an important, additional design consideration in all types of environment.

Significant savings in energy consumption, and therefore, cost of providing lighting without reducing standards can be achieved by applying an "Energy effective design" approach to lighting installations.

Design criteria : The level and quality of the lighting provided by a given installation can be described by means of the following six parameters:

- a) **Lighting level :** Three different levels of lighting can be established, depending on the type of interior, and the activity carried out:
- The minimum for circulation area.
 - The minimum for working interiors
 - The optimum for working interiors.

For the first two levels it would be seen reasonable to choose the perceptibility of the features of a human face as the minimum criterion for adequate lighting levels, where as for the optimum level in working interiors the preferred luminance of the task is of major importance. twenty (20-lux) is regarded as the minimum illuminance value for all circulation (non working) areas. The illumination of all working areas within a building shall be a minimum of 150 lux.

The range between 1000 and 2000 lux appearing to be the optimum for working interiors.

- b) **Luminance distribution in the field of view :** The distribution of luminance within the field of vision should be regarded as supplementary to the establishment of illuminance values within the interior. Of particular importance with regard to luminance distribution are the following:
- Ranges of luminance for ceiling and walls.
 - Luminance distribution in the task area.
 - Avoidance of glare by limiting the luminance of luminaries and windows.
- c) **Glare :** Glare is experienced if lamps, luminaries, windows or other area are too bright compared with the general brightness in the interior, glare can be direct or reflected. Glare can take either of two forms-the first is known as disability glare and the second is discomfort glare. The disability glare impairs vision of object and the discomfort glare is generally experienced as a feeling of discomfort. In interior lighting practice discomfort glare is likely to be more of a problem than disability glare. Measure to control discomfort glare caused by the luminaire will normally take care of disability glare also.
- d) **Modeling :** The general appearance of an interior is enhanced when its structural features and the people and objects within are lighted so that form and texture are revealed clearly and pleasingly. The lighting must not be too directional or it will produce unpleasantly harsh shadows; neither should it be too diffuse or the modelling effect will be lost entirely.

- c) **Colour**: The colour qualities of a lamp are characterized by two different attributes:
- Its colour appearance (Which may be described by its colour temperature)
 - Its colours rendering capabilities which affect the colour appearance of objects illuminated by the lamp.

Colour appearance white light sources may be loosely divided into three groups according to their appearance:

- Cool (bluish white)
- intermediate (white)
- warm (reddish white)

The higher the illuminance the "whiter" should be the colour of the light source.

Table : 2
General Impressions Associated with Different Illuminances and Colour Appearances.

Illuminance (lux)	Associated Impression		
	Colour Appearance		
	Warm	Intermediate	Cool
< 500	pleasant	neutral	cool
500-1000	Pleasant to stimulating	neutral to pleasant	cool to neutral
1000-2000	stimulating	pleasant	neutral
2000-3000	stimulating to unnatural	pleasant to stimulating	pleasant
≥ 3000	unnatural	stimulating	pleasant

Table : 3
Lamp Colour Rendering Groups

Colour rendering Group	Range of colour Rendering index Ra	Colour Appearance	Examples of Use
1	Ra ≥ 85	Cool	Textile industries, paint & printing industries
		Intermediate	Shops, hospitals, Display lighting
		Warm	Homes, hotels, restaurants
2	70 ≤ Ra < 85	Intermediate	Offices, schools, department store, fine industrial work
3	40 ≤ Ra < 70		Interiors where colour rendering is of comparatively minor importance
4 (Special)	Lamps with unusual colour rendering properties.		Special applications
Note	Certain applications e.g. colour matching, may be extremely critical with regard to the colour rendering properties of the lamps used. Here, the minimum colour rendering index used should be 90.		

- 6) **Hard ware Aesthetics**: A luminaire is judged in terms of shape, colour and degree of sophistication. This judgement of the single unit is carried over to the remainder of the luminaires comprising the installation. And a defect in one will be assumed to be present in all the rest.

1.2.2 **Planning the Brightness pattern**: The Brightness pattern seen within an interior is composed of three parts: brightness of the task itself, brightness of the immediate background of the task and brightness of general surroundings of walls, ceiling, floor, equipment, furnishing etc.

The illumination of all working areas within a building shall be a minimum of 150 lux. where work takes place over the whole utilizable area of a room the general illumination over that area should be reasonably uniform and the diversity ratio of minimum to maximum illumination shall not be less than 0.7.

When the task brightness appropriate to an occupation has been determined the brightness of the other parts of the room shall be planned to give proper emphasis to visual comfort and interest. The recommended brightness relationship is shown in Table 4

Table : 4
Brightness Relationship Between Task, Adjacent Sources and Surroundings.

For high task brightness (above 100 cd/m ²) Maximum ratio between task brightness and the adjacent sources like table tops	3 to 1
Maximum ratio between task brightness and illumination of the remote areas of the room not being used as work	10 to 1
For low and medium task brightness (below 100cd/m ²)	The task must be brighter than both the background and the surroundings; the less critical is the relationship

1.2.3 Luminance And Illumination

Luminance (Symbol L) : Brightness was the term formerly used for luminance. The luminous intensity per sq. cm. or sq. m. of the apparent area of a source of light or of an illuminated area is known as the luminance. It is expressed in lamberts. Millilamberts or foot-lamberts.

Lambert is the brightness of a perfectly diffusing surface which effects or radiates one lumen per sq. cm. The milli lambert is one thousandth of this value.

Foot lambert is the brightness of a surface which reflects one lumen per sq. ft.

Apparent area is the projection of primary or secondary light source on to a flat area which is perpendicular to the direction of vision. With a spherical fitting the apparent area is equal to the area of the diametrical cross-section of the sphere.

The conversion factors for various units of illumination and luminance are given in Tables 22 and 23 respectively.

The two terms illumination and luminance are often confused. The illumination indicates the number of lumens impinging on a unit area and has nothing to do with the reflection characteristics of the lighted surface. As against this, the luminance of a surface is dependent upon illumination as well as its reflection characteristics.

When there is a book on a table, the illumination is same for the book and the table but the luminance of the book is greater than that of the table.

The luminance of a light source or a reflecting surface is equal to the light intensity divided by the apparent surface area i.e.

$$L = \frac{I}{S}$$

Where L = Luminance in cd/cm²

I = luminous intensity in candela.

S = apparent area in cm²

The luminance of a diffusely reflecting area is equal to the product of the illumination and the reflection factor divided by the factor 3.14.

A diffusely reflecting area receiving an illumination of 500 lux and having a reflection factor of 40% has a luminance of $\frac{500 \times 0.4}{3.14} = 64 \text{ cd/m}^2$

1.2.4. Lighting Calculation.

Lighting calculations: Horizontal illuminance-defined in terms of average illuminance on the working plane.

Working plane is an imaginary horizontal plane considered to be at the height of the work above the floor (normally 0.75m sitting; or 0.85m standing) and covering the entire floor area.

Distribution of luminous flux from lamp :

$$\text{The average illuminance } \text{lm/m}^2 = E = \frac{Q}{A} \times UM \text{ or } Q = \frac{EA}{UM}$$

Where Q = Total luminous flux of the lamps

A = area of the working plane. (m²)

U = utilization factor which is the ratio of the lumens actually received by a particular surface to the total lumens emitted by a luminous source.

M = maintenance factor : The ratio of the average illuminance, on the working plane after a specified period of the use of a lighting installation to the average illuminance obtained under the same conditions for the same lighting installation when new. It is also called the depreciation factor that means :

$$M = \frac{\text{illumination under actual condition}}{\text{illumination when everything is perfectly clean}}$$

The utilization factor is dependent on the following factors :

1. The type of lighting system, (direct or indirect etc)
2. The type and mounting height of the fittings.
3. Reflectance of ceiling, wall & working plane.
4. Room index, K (shape and dimension of room)

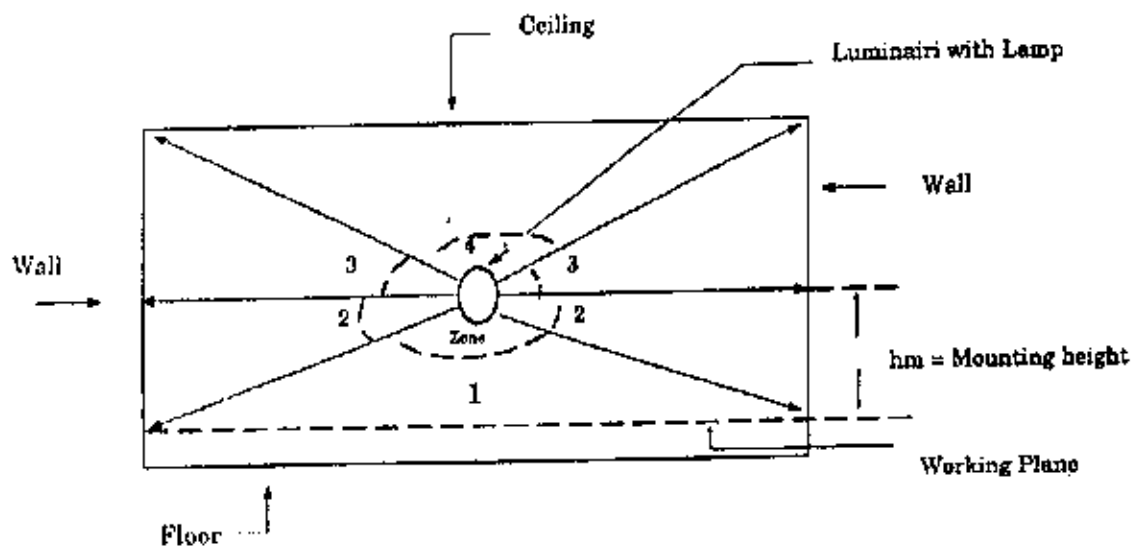


Fig. 2

Distribution of the luminous flux from the lamp is shown in the above picture. The light of zone:

- 1) Striking direct to the working plane,
- 2) Striking the wall area below the luminaire,
- 3) Striking the upper wall area,
- 4) Striking the ceiling,

The room index, K is a function of the room dimensions and is calculated using the formula :

$$K = \frac{Lb}{hm(l+b)} \text{ Where } \begin{array}{l} l = \text{room length} \\ b = \text{room breadth} \\ hm = \text{mounting height of the luminaires.} \end{array}$$

The number of luminaires length wise L and the number of luminaires cross wise C for each of the values of the standard series of room indices are :

K	0.6	0.8	0.1.0	1.25	1.5	2.0	2.5	3	4	5
L	2	2	3	3	4	4	5	6	8	10
C	1	2	2	3	3	4	4	4	5	6

Reflection factor : ratio of light reflected from a surface to the total light falling on the surface. It varies with the roughness of the surface as well as the darkness of the colour.

Unless the reflection factors are known the triplet 0.7/0.5/0.3 shall be used for the offices as the reflectances of ceiling, wall and working plane respectively for light surface colours.

For other premises reflection factors are 0.7/0.5/0.1 in case of ceiling, walls and working plane respectively. Typical reflection factors of smooth coloured surfaces are given in table below:

Table - 5

Reflection factors of smooth coloured surfaces :

Colour	Reflection factor
Flat white	0.75 - 0.85
Ivory	0.7 - 0.75
Yellow	0.55 - 0.65
Light green	0.4 - 0.5
Grey	0.3 - 0.5
Blue	0.25 - 0.35
Red	0.15 - 0.2
Dark brown	0.1 - 0.15
Buff	0.6 - 0.7
Light tan	0.45 - 0.55

The number of luminaires required to produce a specified illuminance can be found out from the equation

$$E = \frac{Q}{A} UM$$

$$Q = \frac{E A}{UM}$$

The required number of luminaires is thus given by

$$N = \frac{Q}{Q1n} \text{ Where :}$$

Q1 = Luminous flux of one lamp.

Q = Total luminous flux of the lamps

n = Number of lamps per luminaire

A = Area of the surface illuminated in square meter (m²)

E = The desired illuminance in lux (lm/m²)

M = Maintenance factor

U = Utilization factor which takes into account the efficiency of the flood light/fittings and the light losses (luminous efficiency).

$$U = \frac{\text{lumens actually received on working plane}}{\text{lumens emitted by the light source.}}$$

For direct lighting it varies between 0.4 and 0.6, for indirect lighting it varies between 0.1 and 0.35.

Application recommendation :

- a) An acceptable illuminance uniformity where reflector luminaires for tubular fluorescent lamps are concerned is obtained if the distance between the row (s) of luminaires does not exceed 1.5 times their height above the working plane.

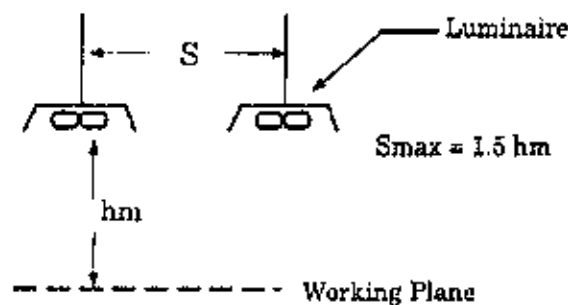


Fig - 3

Figure - 3 Shows the Spacing of fluorescent lamp as a function of mounting height to obtain uniform illuminance.

- b) For mounting heights above 5m high intensity discharge lamps will offer a more economical solution.
- c) Multistory buildings generally have smooth white ceilings at a height of between 2.8m to 3.5m, which can serve as extended reflectors for the purpose of obtaining a better diffusion of the light and an improved luminance pattern.
- d) A minimum horizontal illuminance at ground level of 10 lux is recommended for approach roads, car parks and main entrances.
- e) Patients Room : The lighting for patients rooms should be installed in such a way as not to cause any discomfort glare to patients in the room including those patients whose field of view may include only the ceiling and to the medical staff.

Local lighting over the patients bed should be sufficient to provide good illumination for reading, hand work etc. Illuminance at the bed head should be between 100 & 300 lux over the full width of the bed. The illuminance of the luminaires as seen by both patients and medical staff should not exceed 350 cd/m². There should be a light switch located within reach of the patient.

Night lighting intended for observation of patients cause the minimum disturbance to other patients in the room. An illuminance of between 5 to 20 lux, restricted to the bed-heads, is recommended. The lights should be located at the bed, should not be within reach of the patients.

Artificial lighting to Supplement Daylight : The need for general Supplementary artificial lighting arises due to diminution of daylighting.

Supplementary lighting shall be used when illumination due to daylight falls below 150 lux on the working plane

The requirements of supplementary artificial lighting when daylight availability becomes poor

Cool daylight fluorescent tubes are recommended with semidirect luminaires. To ensure a good distribution of illumination the mounting height should be between 1.50m above the work plane for a separation of 2.0 to 3.0m between the luminaires.

Maintenance factor : The values given below are based upon installation using discharge lamps & luminaires.

Table - 6

Room Category	Total Maintenance factor
Clean	0.8
Average	0.7
Dirty	0.6

1.2.5 Recommended values of illumination : The initial illuminance should be higher than the recommended values to allow for the fact that the illuminance inevitably drop below the recommended values Recommended values of illumination are given in the tables below.

Table - 7
Recommended Values of Illumination for Residential Buildings.

Area or Activity	Illuminance (Lux)
Dwelling houses	
Bedrooms	
General	50
Bed-head, Dressing Table	150
Kitchens	200
Dinning rooms (tables)	100
Bathrooms	100
General	300
shaving make-up	100
Stairs	100
Lounges	100
Garages and porches	70
Sewing and dining	600
Reading (casual)	150
Home work and sustained reading	300
Hotels	
Entrance halls	150
Reception and accounts	300
Dining rooms (tables)	100
Lounges	150
Bedrooms	
General	100
Dressing tables, bed heads etc.	150
Writing rooms (tables)	300
Corridors	70
Stairs	100
Laundries	200
Kitchens	
Food stores	100
Working areas	250
Goods and passenger lift	70
Cloak-rooms	100
Above mirror in bathrooms	300

Table- 8
Recommended Values of Illumination for Educational Buildings.

Area of Activity	Illuminance (Lux)
School and College Assembly halls	
General	150
When used for examinations	300
Platforms	300
Class and Lecture Rooms	
Desks	300
Black boards	250
Embroidery and sewing rooms	500
Laboratories	300
Art rooms	400
Office	300
Staff rooms and common rooms	150
Corridors	70
Stairs	100
Canteen room	250

Table - 9
Recommended Values of Illumination for Health Care Building.

Area of Activity	Illuminance (Lux)
Hospitals and Clinics	
Reception and waiting rooms	150
Out patient department	150
Wards	
General	100
Beds	150
Operating theatres	
General	300
Tables (with adjustable operation lamp lighting)	
Minor	2000
Major	5000
Doctors examination rooms	150
Radiology departments	100
Casualty	150
Stairs and corridors	100
Dispensaries	250

Table - 10
Recommended Values of Illumination for Assembly Buildings

Area or Activity	Illuminances (Lux)
Cinemas	
Foyers	150
Auditorium	50
Corridors	70
Stairs	100
Libraries	
Shelves (stacks)	100
Reading rooms (newspapers and magazines)	200
Reading tables	300
Book repair and binding	300
Cataloging, sorting and stock rooms	150
Museums and Art Galleries	
Museums	
General	150
Displays	Special lighting
Art galleries	
General	100
Paintings	200
Restaurant	
Dining rooms	100
Cash desks	300
Self-carrying counters	300
Kitchens	200
Cloak-rooms and toilets	100
Theatres	
Foyers	150
Auditorium	70
Corridors	70
Stairs	100
Sports Centre	
Halls	150
Swimming pools	150
Tennis court, Table Tennis badminton (Tournament)	300
Volley ball (Tournament)	300
Shooting ranges (On target)	200
Foot ball (Competition)	500

For sports : Table - 11

Type of Sport	Horizontal illuminance (lux)	
	Recreation and Training	Competition
Foot ball	75	200-500
Hand ball	75	300
Gymnastics	75	150
Base ball	200	300
Tennis	200	300-500
Volley ball (indoor)	200	300
Diving	200	400
Badminton (indoor)	200	300
Hockey	200	300
Swimming	150	300
Shooting	200	200

Power consumption of Fluorescent lamp
(Approximate)

Table - 12

Length of lamp (with holder)	Colour	Power watt	Burning hour with sufficient light	Power consumption in choking coil watt	Remarks
457mm (1'-6")	Warm white & natural	15	2500	12	If the lamp is switched OFF & ON frequently, the burning hour will be changed
608mm (2'-0")	..	20	2000	12	
608mm (2'-0")	..	40	2500	12	
914mm (3'-0")	..	30	2500	12	
1219mm (4'-0")	Day light and warm white	40	2500	12	
1524mm (5'-0")	Natural	60	3000	20	

- 1.3 Light fittings : lamp and its fitting, globe, reflector etc shall be regarded as one unit . They shall be designed to suit each other to give desired light.
- 1.3.1 Light fittings are classified in to Five Categories according to the proportion of total light out put in the lower hemisphere:
- (a) Direct fittings, gives 90-100% light downwards.
 - (b) Semi direct fittings gives 60-90% light down wards.
 - (c) General diffusing fittings, give 40-60% light downwards
 - (d) Semi indirect fittings gives 10-40% light downwards
 - (e) Indirect fittings gives 0-10% light downwards.

Lumens of philips incandesent lamp at 220-230V.
(Holder size E27 & E40)

Table 13

Lamp	40W	60W	100W	150W	200W	300W	500W	1000W	2000W
Argenta Super Lux	400	670	1280	2060	2900	--	--	--	-- Argenta K
	375	640	1200	1880	2650	--	--	--	-- Argenta
Standard	385	650	1240	1980	2800	-	-	-	-
Inside Frosted standard	430	730	1380	2220	3150	--	-	-	-
Clear standard	430	730	1380	2220	3150	4850	8400	18800	40000

Table 14
Luminous intensity (cd)

	40W	60W	100W	150W	300W
Blown-Bulb reflector					
R 50 lamp	460				
R 63 lamp	500	860			
R 80 lamp	475	850	1825		
R 95 lamp	-	-	1650		
R 125 lamp	-	-	-	2500	5500
Pressed glass Reflector :					
PAR- 38 Flood lamp	-	-	2150	3400	-
PAR- 38 Spot lamps	-	-	6500	9500	-
PAR- 38 Cool Flood	-	-	-	3400	-
PAR- 38 Cool spot	-	-	-	9500	-
PAR- 56 Floor	-	-	-	-	24000
PAR- 56 wide flood	-	-	-	-	10000
PAR- 56 spot	-	-	-	-	50000

Table - 15
Lumen output (lm) of Halogen Flood light lamp (Philips)

Double Ended type	200W	300W	500W	750W	1000W	1500W	2000W
12094R	3200	-	-	-	-	-	-
12113R	-	5100	-	-	-	-	-
7785R	-	-	9500	-	-	-	-
12117R	-	-	-	15500	-	-	-
12013R	-	-	-	-	22000	-	-
13021R	-	-	-	-	-	33000	-
12110R	-	-	-	-	-	-	44000
Single ended type	100W	150W	250W				
	1400	2250	5000				

Table - 16
Incandescent Flood light lamps (Luminous flux lm)

Type	Wattage (220-230V)	Luminous Flux(lm)
120E	100W	1050
123E	250W	3250
125G	500W	8000
6036G	1000W	19000
7083U	100W	2250
162C	500W	12600

Table - 17
Quartz Halogen theatre lamps (220V/230V/240V)

Type	Watts	Average life in hr
6800C	500	750
6820P	500	300
6908P	650	750
6908C	650	750
6946P	1000	750
6946C	1000	750
6997C	1000	600

Table - 18
Flourescent lamps (220V), Standard (construction

Wattage (W)	Length of lamps (mm)	Luminous flux(lm)
8	288	350
16	720	950
20	590	1250
40	1200	3200

Table - 19
High pressure Mercury Vapour lamp (220V)

Wattage (W)	Holder size	Luminous flux(lm)
80	E27	2000
125	E27	6300
250	E40	13500
400	E40	23000
1000	E40	55000

Table - 20
Metal Halide lamps

Wattage	Voltage	Holder size	Luminous flux (lm)
250	220	E40	17000
360	220	E40	26000
1000	220	E40	80000
2000	380	E40	190000
(380V)	380	E40	300000

Table - 21
High pressure sodium Vapour lamps (220V)

Wattage (W)	Holder size	Luminous flux(lm)
150	E40	14000
250	E40	25000
400	E40	47000
1000	E40	120000
45	E40	2600
60	E40	4000
85	E40	6200
140	E40	10200

Conversion Factor for illumination Units:

Table - 22

Unit	lm/ft ²	Lux	Foot-candle
One lm/ft ²	1	10.76	1
One lux	0.093	1	0.093
One foot - candle	1	10.76	1

A source of one candela emits a total of 12.57 lumens. (= 4 π lumens)

Conversion Factors for Brightness Units

Table - 23

Unit	cd/in ²	cd/cm ²	cd/ft ²	Lamberts	Foot lamberts
One Candela per sq.in.	1	0.155	144	0.487	452.40
Per sq.cm.	6.45	1	929	3.142	2919
per sq.ft.	0.007	0.001	1	3.0034	3.14
One Lambert (one lumen/sq.cm)	2.054	0.318	295.7	1	929
One Foot lambert (one lumen/sq.ft.)	0.002	0.0003	.318	.001	1

For practice purpose of illumination in lux may be divided by 10 to obtain illumination in lumen per sq. m.

Table - 24

Building Flood Lighting : Values are for the main facades of a bldg. (according to bldg. materials used & brightness of surroundings)

Materials	Surroundings poorly lit (Lx)	Surroundings brightly lit (Lx)
Plaster :		
Light	30	120
Dark	100	400
Lime stone sand stone :		
Light	40	160
Dark	80	320
Terra cotta concrete :		
Light	50	200
Dark	80	320
Granite :		
Light	50	200
Dark	150	500
Brick :		
Light	30	120
Dark	150	500
Marble :		
Light	30	120
Dark	300	900

1.3.2. Calculation of number of flood light : The lumen Method :

There are two methods of calculating the type & number of flood lights needed to achieve the desired illuminances. The lumen method-should be used when dealing with large facades- the luminous intensity method- for high towers, chimneys etc. The total number of lumens directed on

the facade by all the lamps = $QT = \frac{EA}{U}$

Where E = the desired illuminance, in lux.

A = the area of the surface illuminated in m²

U = the utilization factor which takes into account the efficiency of the flood light and the light losses (luminous efficiency)

∴ Number of flood lights = $\frac{QT}{Q}$, where Q = Lumens of each flood light.

In practice an average utilization factor of between 0.25 to 0.35 may be reckoned with.

Table - 25

Illuminance	Remarks
0.2 lux	Minimum for safe movement, so obstacles positively detected.
5 lux	Average for "safe" facial recognition.
20 lux	Attractive lighting.
1.3.3	<p>Lamp caps : The cap of a lamp provides the means for mounting it in to a lamp holder. Mainly there are two types of caps :</p> <ol style="list-style-type: none"> 1) B-pin or bayonet type (B-15, B-22) 2) E-Screw type (E14, E-27)
1.3.4	<p>Maintenance of Fluorescent lamps :</p> <p>The light out put of a Fluorescent lamp amounts to about 70 lumens per watt (20,40,80 wtubes).</p> <p>Life span of Fluorescent lamp is 7500 hrs. It is affected by both high and low voltage, frequency of switching and blinking.</p> <p>The average life is for 3 burning hours per switching operation.</p> <p>Light out put is reduced by 15 to 20% after 4000 hrs operation.</p> <p>The effect of voltage variation in the case of fluorescent lamps is less marked as compared to the incandescent lamps. However, their life and performance are adversely affected both by low and high voltage and, therefore, wiring should be carried out in such a manner as to cause minimum voltage fluctuation.</p> <p>Low voltage will cause starting difficulties and blinking. High voltage will damage the lamps and auxiliaries by over heating.</p> <p>The best efficiency of fluorescent lamps is obtained at 20°-25°C operating temperature. It decreases rapidly when a lamp is operated at a lower temperature or is exposed to cold wind drafts.</p> <p>Operating Suggestions. (a) A fluorescent lamp should start up with little blinking. Blinking indicates a defective starter, low voltage or a defective tube.</p> <p>When the active material on the electrodes is used up the lamp simply blinks on and off, sometimes with a shimmering effect during the period the lamp remains lighted. Most fluorescent lamps fail in this manner. Both the choke and the starter will get damaged due to overheating if this condition is allowed to persist. The lamp or the starter must be removed immediately to prevent damage.</p> <ol style="list-style-type: none"> b) Ensure correct voltage. c) Replace starter every time a tube is changed. Do not wait for the starter to fail as a bad starter will shorten the life of the lamp. <p>Trouble Shooting. Failure of a lamp to light up may be due to any one or more of the following causes:</p> <ol style="list-style-type: none"> 1) a defective tube. 2) a defective starter. 3) a defective choke. 4) defective and loose holders. 5) defective wiring. <p>If only the ends of a lamp remain lighted, it indicates a short circuited starter.</p> <p>Blinking on and off of a lamp is the usual indication of its normal failure. Try a new starter and if the blinking still continues, renew the lamp. Other causes of blinking are :</p> <ol style="list-style-type: none"> 1) Low circuit voltage 2) low ballast rating 3) low temperature 4) cold drafts

Blackening of Fluorescent Lamps. With use, lamp walls blacken a little and dark rings appear near the ends due to the deposition of active material from the electrodes. However, their occurrence within 500 hours indicates premature "sputtering off" or shedding of the active materials which may be due to any one or more of the following causes :

- 1) High or low voltage
- 2) Loose holder contacts causing blinking.
- 3) Defective starter causing blinking

Difficult starting brings about premature blackening and also shortens the life of a fluorescent lamp.

Radio Interference; The mercury arc in a fluorescent lamp sets up continuous series of radio waves, which interfere with the reception of radios and other wireless receivers. This radiation can reach the radio receivers in two ways. :

- i) By direct radiation from the lamp to the aerial.
- ii) As a result of line feedback from the lamp to the radio

The direct radiation can be controlled by placing the aerial as away from the lamps as possible. There is little interference if the distance exceeds 2 metres. Where the distance is less or additional precautions are desired, shielded lead in wire with grounded shield should be used. The radio, the lamp fixtures and the neutral should all be effectively grounded.

- 1.4. **Road lighting :** The trend, from the point of view of cost and energy, is always for low pressure sodium to offer the best solution.

The lowest cost and energy consumption are usually obtained at mounting heights close to the widths of the total road for single sided and to half the width of the total road for opposite and twin-central arrangements.

Security lighting : Recommended illuminances for security lighting is given below :

Table - 26

Illuminance	Remarks
1 lux	Minimum for security lighting in areas where there is no adjacent lighting, necessary to positively detect an intruder.
5 lux	Recommended average; facilitates positive orientation; corresponds to the luminance recommended for feeder roads.
20 lux	Recommended for areas with adjacent road lighting or flood lighting; human features are recognizable; corresponds to the luminances recommended for main roads.

- 1.5. **Illumination level :** An idea of illumination levels is given in the table below :

Table - 27

Summer-Midday in open	1,00,000 lux
Winter-midday in open	10,000 lux
Summer-Midday in balcony	2000-5000 lux
Summer-Midday behind a window	1000-3000 lux
Sunrise and sunset	500 lux
Full moon and bright sky	0.25 lux
Office with good lighting	600-800 lux

- 1.6 : **Some applications**

- a) A room 8m x 12m is lighted by 15 lamp to a fairly illumination of 100 lm/m². Out put of each lamp is 1600 lm. Calculation of utilization factor or coefficient of utilization :-
 lumens emitted by the lamps = 15 x 1600 = 24000 lm
 lumens received by the working plan of the room = 8 x 12 x 100 = 9600 lm.

$$\text{Utilization factor or coefficient} = \frac{9600}{24000} = 0.4 \text{ or } 40\%$$

- b) The illumination in a drawing office 30m x 10m is to have a value of 250 lux and is to be provided by a number of 300w filament lamps. If the utilization factor is 0.4 and the depreciation or maintenance factor is 0.9, the luminous efficiency of each lamp or efficiency is 14 lm/w, then determination of the number of lamps required :-

$$Q = \text{Total lumens} = \frac{E \times A}{U \times M}$$

$$E = 250 \text{ lm/m}^2$$

$$A = 30 \times 10 = 300 \text{m}^2$$

$$U = 0.4$$

$$\text{or } Q = \frac{250 \times 300}{0.4 \times 0.9} = 208,333 \text{ lm}$$

$$M = 0.9$$

$$\text{Flux emitted per lamp} = 300 \times 14 = 4200 \text{ lm}$$

$$\text{Number of lamps required} = \frac{208333}{4200} = 50$$

- c) Designing a suitable lighting scheme for a factory 120 m x 40m with a height of 7m, illumination required is 60 lux, enlightened by 40w fluorescent tubes of 45 lm/w efficiency, maintenance factor = 0.8 Utilization factor = 0.5 : the number, location and mounting height of the fluorescent tubes will be :-

$$Q = \frac{60 \times 120 \times 40}{0.8 \times 0.5} = 720000 \text{ lm. Flux per tube} = 45 \times 40 = 1800 \text{ lm}$$

$$\text{No. of fluorescent lamps reqd.} = \frac{720000}{1800} = 400$$

$$\text{If twin tube fittings installed the No. of fitting} = \frac{400}{2} = 200$$

Assuming that the working plane is 1m above the floor level and the fittings are fixed 1m below the ceiling. To get the space/height factor of unity, if we arrange 200 Nos. of fitting in this room we are to fix each fitting 1.2m below the ceiling, the working plane usually 1m above the floor. Then the spacing of fittings will be 4.8m. These 200 fittings can be arranged in 8 rows of 25 fittings each.

- d) A drawing hall in an engineering College is to be provided with lighting installation with metal filament lamps. The hall is 30m x 20m x 8m (high). The mounting height is 5m and the required level of illumination is 144 lm/m². Assuming utilization coefficient = 0.6, maintenance factor = 0.75, space/height ratio = 1, efficiency for 300w lamp = 13 and for 500w lamp = 16, the size and number of single lamp luminaires and their spacing layout estimate can be prepared in the following way :

$$\text{Total flux } Q = \frac{30 \times 20 \times 144}{0.6 \times 0.75} = 192000 \text{ lm}$$

$$\text{Lumen output per 500w lamp} = 500 \times 16 = 8000$$

$$\text{No. of 500w lamp required} = \frac{192000}{8000} = 24$$

$$\text{No. of 300w lamp required} = \frac{192000}{3900} = 49$$

The 300w lamps can not be used because their number cannot be arranged in a hall of 30m x 20m with a space/height ratio of unity. However, 500w lamps can be arranged in 4 rows of 6 lamps each with a spacing of 5m both in the width and the length of the hall.

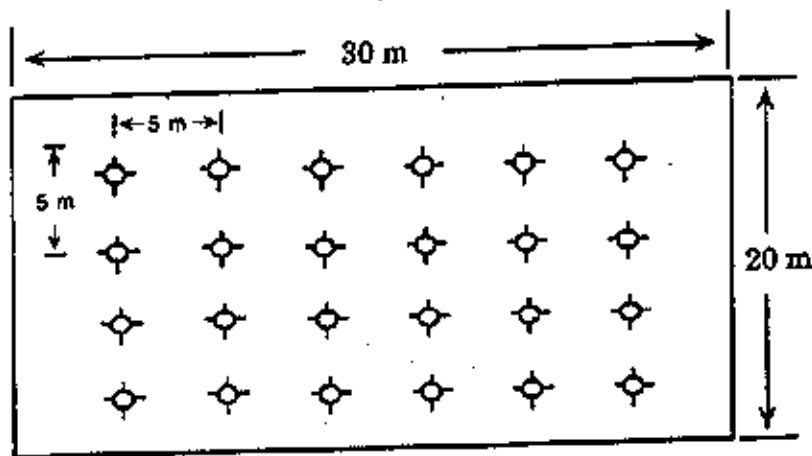


Fig - 4

Arrangement of 24 fittings.

- e) A foot ball pitch $120 \times 60 \text{ m}$ is to be illuminated for night play by similar banks of equal 1000 w lamps supported on twelve towers which are distributed around the ground to provide approximately uniform illumination of the pitch. Assuming that 40% of the total light emitted reaches the playing pitch and that an illumination of 1000 lm/m^2 is necessary for television purposes consider over all efficiency of the lamp 30 lm/w. No. of lamps on each tower is calculated in the following way :-

$$\begin{aligned} \text{Area to be illuminated} &= 120 \times 60 = 7200 \text{ m}^2 \\ \text{Flux required} &= 7200 \times 1000 = 7.2 \times 10^6 \text{ lm} \\ \text{Since only 40\% of the flux emitted reaches the ground, the total luminous flux required to be produced is} &= \frac{7.2 \times 10^6}{0.4} = 18 \times 10^6 \text{ lm.} \\ \text{Flux contributed by each Tower bank} &= \frac{18 \times 10^6}{12} = 1.5 \times 10^6 \text{ lm} \\ \text{out put of each } 1000 \text{ w lamp} &= 30 \times 1000 = 3 \times 10^4 \text{ lm} \\ \text{Hence no. of such lamps on each Tower} &= \frac{1.5 \times 10^6}{3 \times 10^4} = 50 \end{aligned}$$

- f) A drawing hall $40 \times 25 \times 6 \text{ m}$ high is to be illuminated with metal filament gas-filled lamps to arrange illumination of 90 lm/m^2 on a working plane 1 Metre above the floor. Assume coefficient of utilization of 0.5, depreciation factor of 1/1.2 and spacing/height ratio of 1.2, suitable number, size and mounting height of lamps are estimated in the following way.

Size of lamp	200 w	300w	500w
luminous efficiency lm/w	16	18	20

$$\text{Total flux required} = Q = \frac{40 \times 25 \times 90}{0.5 \times 1/1.2} = 216000 \text{ lm}$$

$$\text{Lumen output of each } 200 \text{ w lamp is } 200 \times 16 = 3200 \text{ lm}$$

$$\text{" " " " } 300 \text{ w " " } 300 \times 18 = 5400 \text{ lm}$$

$$\text{" " " " } 500 \text{ w " " } 500 \times 20 = 10,000 \text{ lm}$$

$$\text{No. of } 200 \text{ w lamp required} = \frac{216000}{3200} = 67$$

$$\text{" " } 300 \text{ w " " } = \frac{216000}{5400} = 40$$

$$\text{" " } 500 \text{ w " " } = \frac{216000}{10000} = 22$$

With a spacing/height ratio of 1.2, it is impossible to arrange both 200w and 300w lamp. Hence, the choice falls on 500w lamp. If instead of the calculated 22, We take 24 lamps of 500w, they can be arranged in four rows each having six lamps. Spacing along the length of the hall is $40/6 = 6.67 \text{ m}$ and along the width is $25/4 = 6.25 \text{ m}$

Since mounting height of the lamps is 5m above the working plane, it gives a space/height ratio of $6.67/5=1.33$ along the length and $6.25/5=1.25$ along the width of the hall.

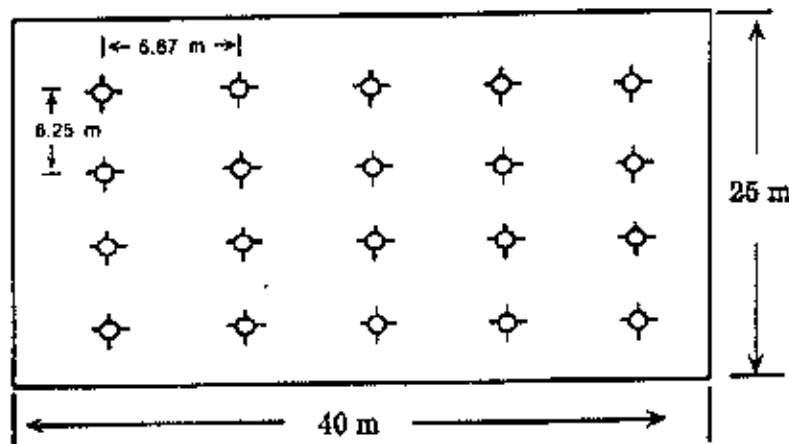


Fig - 5

It is desired to flood-light the front of a building 42m wide and 16m high. projectors of 30° beam spread and 1000w lamps giving 20 lm/w are available.

If the desired level of illumination is 75 lm/m^2 and if the projectors are to be located at ground level 17m away, $U = 0.4$, $M = \frac{1}{1.3}$, Waste light factor $W=1.2$, designing of the scheme :-

$$Q = \frac{EAW}{UM} \quad \therefore Q = \frac{75 \times 672 \times 1.2}{0.4 \times 1/1.3}$$

Here

$$E = 75 \text{ lm/m}^2 \quad = 196560 \text{ lm}$$

$$A = 42 \times 16 = 672 \text{m}^2$$

$$W = 1.2$$

$$U = 0.4$$

$$M = \frac{1}{1.3}$$

Lumen output of each 1000w lamp $20 \times 1000 = 20,000 \text{ lm}$

$$\text{No. of lamps required} = \frac{196560}{20000} = 10 \text{ (say)}$$

With a beam spread of 30° , it is possible to cover the whole length and width of the bldg by arranging the 10 projectors in two rows as shown in the design below.

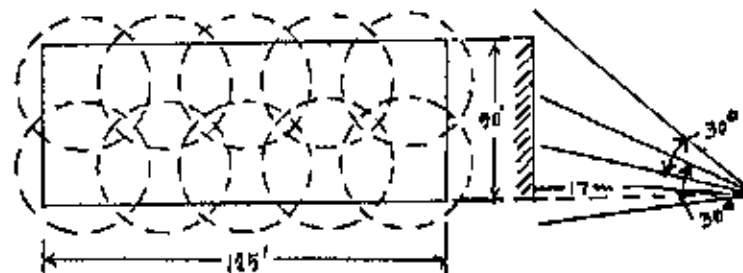


Fig - 6

- h) A Tower 96m long, width 13m. The upper 75m of one face of this tower is to be illuminated. Approximate initial average luminance is to be 6.85 cd/m^2 . The projectors are mounted at ground level 51m from base of the tower. Utilization factor = 0.2; reflection factor of wall = 25% and efficiency of each lamp = 18 lm/w. The number of 1000w flood light projectors required to illuminate as mentioned above is calculated in the following way :

We know that a source of one candela (cd) emits one lumen per steradian. Hence, total flux emitted by it all around = $4\pi \times 1$ lumen.

i.e. 1 cd emits = 4π lumen

$$\therefore E \text{ (is given)} = 6.85 \frac{\text{cd}}{\text{m}^2} = \frac{6.85 \times 4\pi}{\text{m}^2} \frac{\text{lm}}{\text{m}^2}$$

Area to be flood - lighted, $A = 13 \times 75\text{m}^2 = 975\text{m}^2$

$$\therefore \text{Flux required} = Q = \frac{EA}{U}$$

Taking utilization factor into account the flux to be emitted by all the lamps = $\frac{6.85 \times 4\pi \times 975}{0.2}$ lm

Flux emitted by each lamp = $18 \times 1000 = 18,000$ lm

$$\therefore \text{No. of lamp required} = \frac{6.85 \times 4\pi \times 975}{0.2 \times 18000} = 24 \text{ (Approx.)}$$

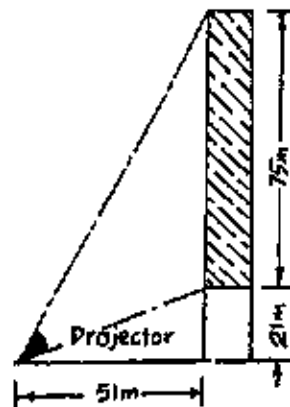


Fig-7

ELECTRICAL INSTALLATION

2.1. House Wiring

An adequately wired home is one that has been wired so that it is completely safe, and so the occupant will get the maximum convenience and utility from the use of electric power, with a minimum of inconvenience.

He must have light available where needed, and the amount needed from permanently installed fixtures or portable appliances. He must be able to plug in lamps, radio and T.V. where he pleases, without resorting to extension cords, even after the furniture is moved around. He must be able to turn lights on and off in any room without stumbling through darkness to find a switch, to move from basement to attic with plenty of light but without leaving an unneeded light turned on behind him.

He must be able to Plug in needed appliances without first unplugging others. He must get full utility out of the appliances by having them heat quickly, and without lights dimming as the appliances are turned on. Circuit breakers/protection devices must trip rarely.

2.1.1. Types of house wiring

Surface/exposed wiring : Runs over the surface of walls and ceilings whether contained in conduit or not is termed as surface/exposed wiring. In this system twin core flat cables/wires may be run on wooden battens and round wires through PVC/G.I. pipes of approved quality. The pipes are fixed on wall/roof by appropriate methods and the cables/wires are fixed on the batten or drawn through pipes by using galvanized metal/non metal clips G.I. or PVC. conduits shall be clamped with saddles at a spacing not exceeding 600 mm to the wall or ceiling using plastic rawal plug with counter sunk galvanized screws. The battens/conduits are installed exposed and run straight on the ceiling or wall surfaces. Batten/conduits on walls shall be run either horizontally or vertically never at an angle.

Twin core flat cables are installed on wood batten and fixed with galvanised steel clips or brass link clips at a spacing not exceeding 100mm.

The single core cables are to be with PVC insulation of 600/1000 volt grade. The multi core cables are to be of PVC insulated PVC. sheathed direct burial type, termite proof with 600/1000 volt grade insulation level. Twin core flat cables for insulation on wood battens are to be with PVC insulation of 600/1000 volt of grade.

The cables, generally of single core, are to be pulled in pipes concealed/exposed without causing any scratch or damage on the insulation of the same. Cable should not be drawn in round more than two 90° bends between the drawing-in boxes and any single bend must not be less than 90°.

Concealed wiring: The wires shall be basically encased in metallic or non-metallic conduits that are buried in roof or floor concrete and concealed in brick/concrete wall.

2.1.4. Service entry :

Over head service connection with covered conductor on catenary wire are mainly for single phase consumers. Three phase service connection may also be received in a building with proper arrangement some of which are shown in the pictures later on.

In over head line systems, service lines are led into buildings, via roof poles or a service mast of 1.5" dia G.I. pipe with goose neck at the top are installed with outer wall of the building with clamp near the energy meter location. The steel catenary wires are connected between the supply pole and the service mast. The insulated cable is tied with the catenary wire and one end of the cable passes through the goose neck and G.I. pipe mast and runs upto the energy meter while the other end is connected to the service line. Figure No.2 to 10 shows several type of service connections. The under ground service cable is laid under ground as per standard practice. The service connection must be drawn from the pole position and never from any position between the poles. An additional lead in for underground cables in cellar and an empty conduit for the service main should be provided to facilitate easy changeover from over head line to underground cable system are dependable in operation, need no maintenance and do not spoil the view of modern housing areas.

Under ground service connection with covered conductor are mainly for 3-phase consumers shall be laid in conformity with the requirements of section "Under ground wiring" as above.

The service connection box should be located on an outer wall of the house beside or opposite to the stair case or in the stair case well if self.

- 2.1.5 Main distribution board (MDB): power from the supply authority is received in the main distribution board from where various branch circuits originates. MDB shall incorporate protective devices like miniature circuit breakers (MCB)/Moulded case circuit breakers (MCCB)/rewireable fuse cutouts and/or combination thereof. These are made of 16 swg sheet steel metal, hammer painted with hinged single or double shutter. The boxes are for concealed in wall or exposed on wall or floor standing type having knock outs for pipe entry into the same. The miniature ckt breakers (MCB) for single phase operation and moulded case ckt breakers (MCCB) for three phase operation of quick make, quick break type with instantaneous magnetic trip elements for functioning on short circuits are housed in the distribution boards for controlling the electrical ckt's for electrical loads of different areas. All wires passing through the metal board shall be protected by rubber or wooden bush at the entry hole. Front clearance of the MDB should be one meter.

The enclosure located in the stair case/entrance of the bldg. shall be dust and vermin proof using sheet steel fabrication of a minimum thickness of 16 swg. The board shall be safe in operation and safe against spread of fire due to short circuit. It should be so located that in case of emergency the power source can be switched off quickly.

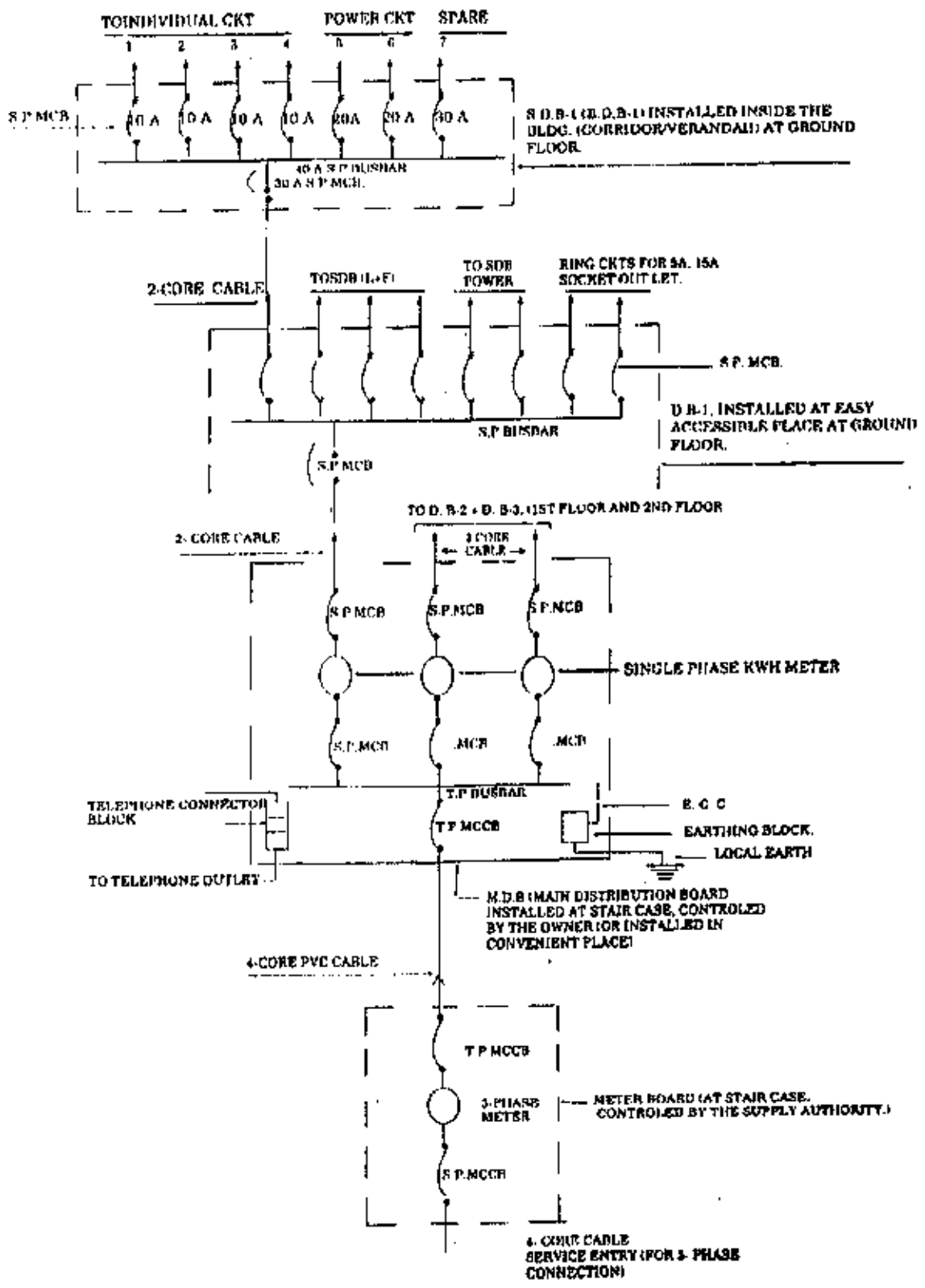
The switch boards should not be erected above gas stoves or sinks, or within 2.5m of any washing unit. Adequate illumination shall be provided for all working spaces around the switch board when installed in doors.

Sub-distribution board (SDB): Enclosure of SDB located in side the bldg. shall be dust & vermin proof using sheet steel fabrication of a minimum thickness of 18 swg. The board shall be safe in operation and safe against spread of fire due to short circuit. It should be so located that in case of emergency the power source can be switched off quickly.

2.1.6 Wiring of S.D.B

- In wiring a SDB total load of the consuming devices shall be distributed, as far as possible, evenly between the number of ways of the board, leaving the spare way(s) for future extension.
- All connection between pieces of apparatus or between apparatus and terminals of a board shall be neatly arranged in a definite sequence, following the arrangement of the apparatus mounted there on, avoiding unnecessary crossings.
- Cable shall be connected to terminals only by soldered, welded or crimped lugs, unless the terminals are of such form that it is possible to securely clamp them without cutting away the cable strands.

- 2.1.7 Power and Telephone cable are laid in separately, the power cable 91cm & the telephone cable about 35cm below the ground level.



TYPICAL DOMESTIC DISTRIBUTION BOARD WITH SERVICE ENTRY (LINE DIAGRAM)

When Telecommunication cable and power cable are laid in one trench the horizontal or vertical separation generally be 0.6 meter (2'). This separation should not be less than 0.4 meter (1'4") in case of single core cable and 0.3 meter (1'-0") in case of multi core cable. The crossing between power and Telecommunication cable should be in right angle as far as possible.

2.1.8 Layout and installation drawing

An electrical layout drawing shall be prepared showing all outlets for lamps, fans, fixed and transportable appliances, motors etc.

All runs of wiring and the exact positions of all points of switch-boxes, MDB, SDB and other outlets shall be marked on the plan of the building. The height of switch boards, MDB, SDB, should be at approximately 1.5m from floor level. Telecommunication (e.g. radio, telephone, music, burglar alarm, call bell and data transmission) circuits shall be indicated separately.

In designing the wiring layout, power and heating sub-circuits shall be kept separate and distinct from lighting and fan sub-circuits. All wiring shall be done on the distribution system with main and branch distribution boards placed at convenient positions considering both physical aspects and electrical load centres. A single line wiring diagram shall be prepared to indicate the wiring system. The single line diagram should clearly indicate the various circuits, cable sizes and protective devices.

2.1.9 Fittings/Fixtures and accessories:

Ceiling rose or any other similar attachment shall not be used on a circuit the voltage of which normally exceeds 240 volts. The ceiling rose shall conform to BDS 116. No flammable shade shall form part of lighting fittings unless such shade is well protected against all risks of fire. Celluloid shade or lighting fittings shall not be used. Normally, only one flexible cord is to be attached to a ceiling rose.

Socket outlets and plugs : There are of 5 amp and 15 amp 240v. rating. There are 2-pin & 3-pin socket in use. The 3-pin sockets are to be mounted on 18 swg. sheet steel box of adequate size. Each 15amp 3-pin socket outlet shall also be controlled by a switch which shall normally be located immediately adjacent thereto or combined therewith. The 3 pin sockets in general are installed on wall with box concealed at skirt level. In situations where a socket outlet is accessible to infants, it is necessary to install an interlocked plug and socket or, alternatively, a socket outlet which automatically gets screened on withdrawal of the plug.

The phase, neutral and earth wire must be connected properly. The 2-pin socket outlets in general are located on the switch boards. The phase wire to the socket-outlet shall be through the switch. The copper earth wire for 5amp socket outlets shall not be smaller in size than 14 swg. The number of socket outlets in a bldg. depends upon the specific requirements of occupants and the type of Bldg. All socket outlets shall conform to BDS 115.

Switch box : Switches locally available are plane and tumbler type. Plane type for concealed installation while tumbler type for exposed installation. The switches are of 5amp ratings and the concealed boxes are to be made of 18 swg. sheet steel with ebonite cover of adequate sizes. The switch boards, in general, are installed concealed/exposed in wall/column at 1.5m from floor level, switches must be connected to the phase wire and the earth wire to earth block located in the switch board. Switch boards shall be installed in the left side (on wall) of the door opening when entering the door (as far as possible).

Fans : Ceiling fans including their suspension shall conform to BDS 818. Fans shall not be placed, relative to the positions of light fittings, in such a way that shadows are thrown on the working planes.

In general, fans in large halls may be spaced at 3 to 3.5m in both the directions. Exhaust fans are necessary for spaces, such as toilets, kitchens, canteen and godowns to provide the required air changes.

Table-1 gives the recommended area as to be served by different sizes of ceiling fans where the height of fan blades is 2.5m above the finished floor level.

Table-2 gives the minimum guide lines for residential occupancy, shall be used to determine the required number of 15A. Switch socket outlets, when actual requirements cannot be ascertained.

Shall be provided for control of every lighting fitting. A switch may control an individual point or a group of points.

Conductors and accessories:

Conductors shall be of copper or aluminium conductors for power and lighting ckts, shall be of adequate size to carry the designed ckt load without exceeding the permissible thermal limits for the insulation. The conductor for final ckt for fan and light wiring shall have a nominal cross sectional area of not less than 1.5mm² for copper conductors

Flexible cables and flexible cords: The minimum cross sectional area of conductors of flexible cords shall be 0.5mm² for copper conductors. Flexible cable or cords shall not be used as fixed wiring unless contained in an enclosure affording mechanical protection.

Flexible cords may be used for connections to portable equipment. For the purpose of this regulation an electric cooker of rated input exceeding 3 kw is not considered to be portable. The flexible cord shall be of sufficient length so as to avoid undue risk of damage to the outlet, cord or equipment and of being a hazard to personnel.

Table - 1

Recommended fan sizes in Rooms

Room Area (m ²)	Fan sweep
Up to 6	915mm
Over to 6 to 9	1220mm
Over 9 to 12	1442mm

Table - 2

Minimum Number of 15A socket outlets

Location	Number of switch socket outlets.
Bed room	1
Living room	1
Drawing room	1
Dinning room	1
Kitchen room	1
Bath room	1
Verandah	1
For refrigerator	1
For Air conditioner	One for each.

MCB/MCCB: The MCB's are normally rated between 5Amp to 60A. and suitable for 250/430v, 50 Hz, operation. The MCCB's are rated at 600V, 50 Hz, for over load and short ckt protection with thermal and magnetic tripping action. The interrupting capacity of MCCB's to be used are recommended as follows:

5 to 60ASPMCB	: 6KA
6 to 100ATP MCCB	: 10KA
150 to 250ATP MCCB	: 25KA
300 to 400ATP MCCB	: 35KA
500 to 1600ATP MCCB	: 50KA
1600 to 3000ATP MCCB	: 65KA

Position of distribution boards (DBS) - The distribution boards are normally installed with the bottom level at 76m from floor level and the maximum height of any ckt breaker should be within 1.8m. from the floor. For floor standing installation proper framing with steel member with adequate strength must be made.

Energy Meters : Single phase or three phase depending on demanded load of the consumer, normally are of indication type-watt-hour meter with cyclometer dial for recording the power consumption. Meters must be sealed before installation. It is to be installed at locations freely accessible to the meter recording personnel. Adequate protection against accidental damages or damage due to electrical fault of meter must be incorporated in the meter box. They should not be installed at a level less than one meter above the ground.

The energy meters should either be provided with a protective covering, enclosing it completely except the glass window through which the readings are noted, or shall be mounted inside a completely enclosed panel provided with hinged or sliding doors with arrangement for locking.

Wooden boards : For small installations connected to a single phase 220volt supply, wooden boards may be used as main boards or sub-boards: These shall be of seasoned teak or other approved quality timber with all joints dovetailed. Wooden boards of different sizes are used as switch boards inside rooms in exposed wiring.

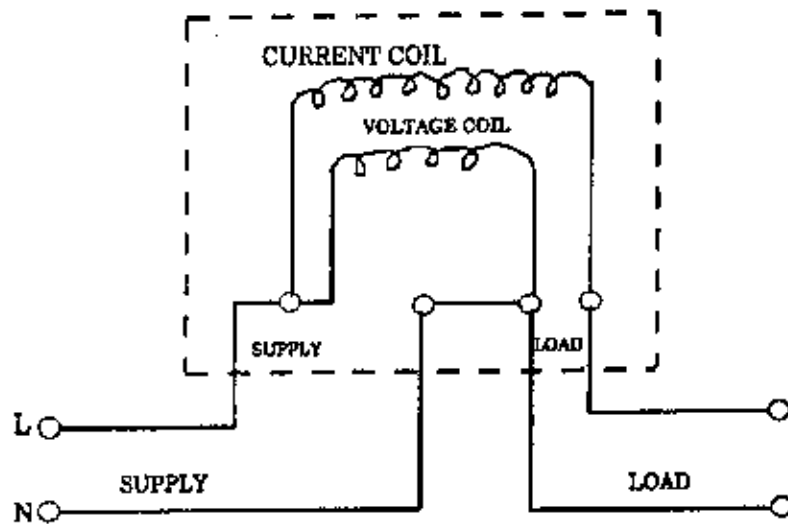
Location of distribution boards : The distribution fuse boards shall be located as near as possible to the centre of the load they are intended to control.

- a) They shall be fixed on suitable position or wall and shall be accessible for replacement of fuses and shall not be more than 2m from floor level.
- b) They shall be either metal clad type, or all insulated type, weather proof type, flame proof type (where necessary), shall be treated with anticorrosive preservative or covered with suitable plastic compounds (in corrosive atmospheres).

2.2. LOAD ESTIMATION

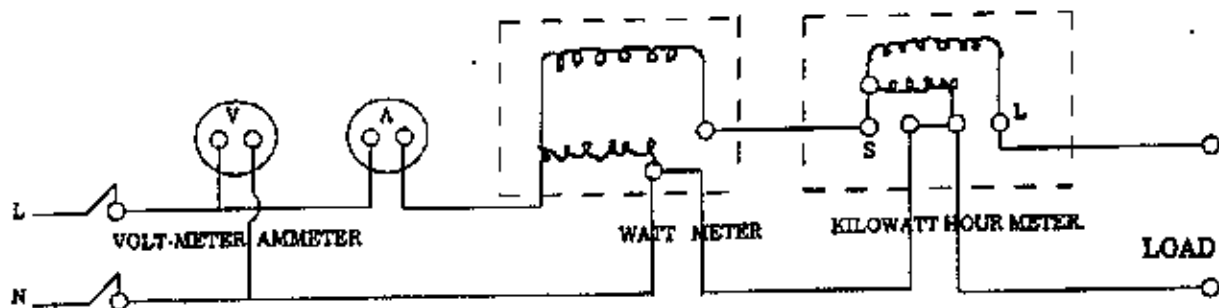
Circuit design is based on primary load estimates of the installations.

In estimating the electrical Load, the rating shown in table-3 shall be taken unless actual values are known or specified.



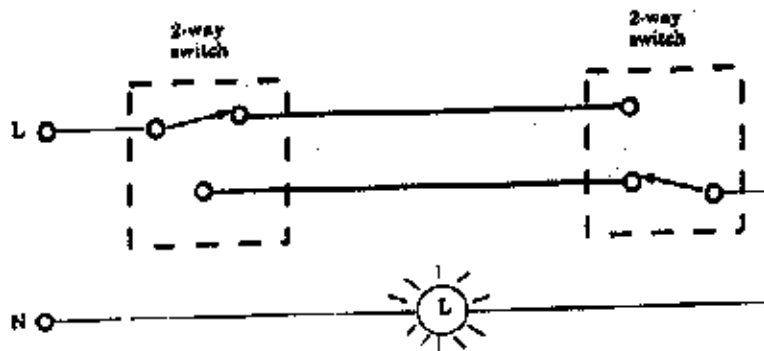
SINGLE PHASE KILOWATT- HOUR METER CONNECTION

FIG-1.a

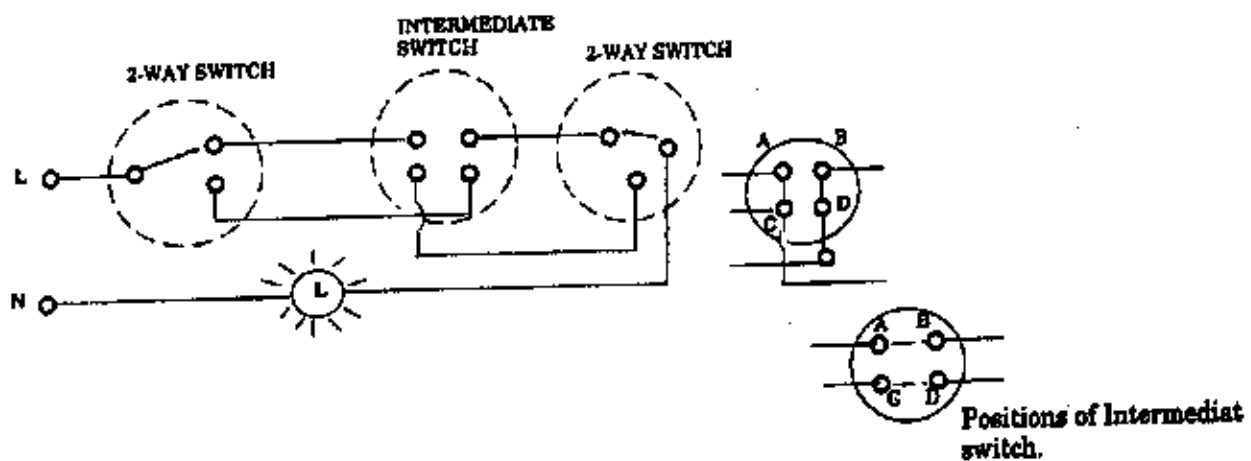


SOME METER CONNECTION

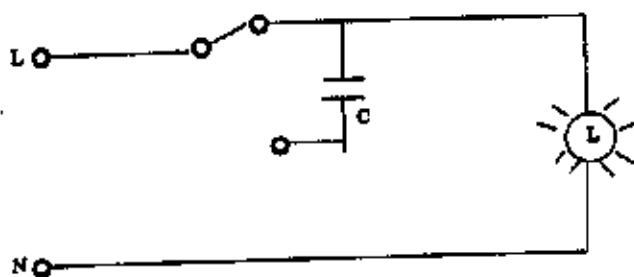
FIG - 1.b



STAIR CASE LAMP SWITCHING FROM TWO POSITION
Fig - 2.a



LAMP SWITCHING FROM 3-POSITION
Fig - 2.b



LIGHT DIMMER
Fig - 2.c

LAMP CAP	CONDENSER SIZE (C)
220 V, 25 W.	1.5 M.F.
- , 40 W.	2 "
- , 60 W.	2.5 "
- , 100 W.	4 "

Table - 3
Load estimates for different fitting/fixtures.

Type of fittings/fixtures	Rating in watts nominal	
Incandescent lamp	100 watt	each
Fluorescent lamp with accessories :		
· length 600mm	20watt	each
· length 1200mm	40watt	each
· length 1500mm	80watt	each
Ceiling/Table fan	70watt	each
Cooker	6000watt	each
Exhaust/pedestal fan	90watt	each
Refrigerator	150-400watt	each
5A socket outlet	200watt	each
15A socket out let	1000watt	each
Electric Heater	500-3000watt	each
For fixed appliances : as per actual/rated load.		

2.2.1. **Maximum demand & diversity:** In determining the maximum demand of an installation or parts there of, diversity shall be taken into account. Table 5 & 4 give some information on the determination of the maximum demand of an installation and the current demand to be assumed for commonly used equipment together with guidance on the application of allowances for diversity.

Table - 4
Current Demand to be Assumed for points of Utilization and Current-using Equipment

Point of Utilization or Current-using equipment	Current Demand to be Assumed
Socket outlets other than 5A socket outlets	Rated current
5A socket outlets	At least 0.5A
Lighting outlet	Current equivalent to the connected load, with a minimum of 100watt per lamp holder
House hold cooking appliance	The first 10A of the rated current plus 30% of the remainder of the rated current plus 5A if a socket outlet is incorporated in the control unit.
All other stationary equipment	Standard rated current or nominal current.

Table - 5
Allowances for Diversity

Purpose of final circuit fed from conductors or switchgear to which diversity applies	Type of premises		
	Individual house hold installation including dwellings of a block	Small shops, stores, offices and business permises	Small hotels, boarding houses, guest houses etc.
1. Lighting	66% of total current demand	90% of total current demand	75% of total current demand
2. Cooking appliances	10amperes+30% f.l.of connected cooking appliances in excess of 10amperes+ 5 amperes if socketoutlet incorporated in unit.	100% f.l. of Largest appliance + 80% f.l. of 2nd Largest appliance + 60% f.l. remaining appliances	100% f.l.Largest appliance + 80% f.l. of 2nd Largest appliance +60% f.l. of remaining appliances
3. Motor(other than Lift motors which are subject to special consideration)	-	100% f.l. of Largest motor +80% f.l.of 2nd Largest motor + 60% f.l. of remaining motors.	100% f.l. of Largest motor + 50% f.l. of remaining motors
4. Water-heater (Thermos-tatically codntrolled)	-	No Diversity Allowable	

f.l = Rated full load current of the current using equipment.

Symbol for Electrical fittings and Application

Description	Symbol	Description	Symbol
Main control or main-distribution board (MDB)		Wall bracket with Incandescent lamp	
Sub-distribution board (SDB)		Water proof wall bracket	
Switch board (SB)		Single fluorescent lamp on ceiling	
Fuseable element		Double fluorescent lamp on ceiling	
Potential transformer		Double fluorescent lamp on wall	
Current transformer		Spot light	
Ampere meter		Capacitor	
Voltmeter		Ceiling fan	
Transformer		Bracket fan	
Circuit breaker		Exhaust fan	
Incandescent lamp on ceiling		Junction Box	
Exit light, surface or pendant		Radio aerial socket	
Exit light, wall mounted		TV Socket outlet	
2-pin socket (single phase)		Aerial for audio / visual	
3-pin socket (single phase)		Fire alarm bell	
Duplex Receptacle		Fire detector	
Triplex Receptacle		Smoke detector	
Special purpose outlet (Described in specification)		Generator	
Single pole, one-way switch		Isolator (Disconnecting switch)	
Two pole, one way switch		Earthing switch	
Two way switch		Conduit concealed pipe in ceiling or wall	
Switch socket for 3 phase connection		Conduit concealed pipe in floor or ground	
Bell		Wiring concealed in floor	
Buzzer		Earth / Ground	
Star/Delta connection		Lightning Arrestor	

2.2.2. Minimum load densities : While estimating the electrical load, the minimum load densities to be considered are those shown in table-6

Table - 6
Minimum load densities :

Type of occupancy	Unit load W/m ² Covered area	
	non A.C.	A.C.
Dwelling : single/multi families (other than Hotels)	25	100
Office bldg/commercial multistoried bldgs.	35	95
Hospitals	40	105
Schools/College	15	90
Large Storage space, Ware house	2	-
Restaurants (Excluding Electric cooking)	20	95
Industrial bldgs(excluding the loads for machine)	20	-
Hotel/motel/apartment house (without cooking loads of Tenants)	30	100
Banks	25	95
Barber shops & beauty parlours	40	100
Departmental store	35	95
Parking area in Commercial Bldg.	4	-

General load 12 W/m² to be considered.

2.2.3 Load forecasting : Load forecasting is the vital subject, which will determine the project cost, ultimately will give a viable system.

Some definitions for estimation are furnished below :

Demand : (average demand) The demand of a system is meant its load requirement (usually, in KW or KVA) averaged over a suitable and specified interval of time of short duration, which comes.

$$= \frac{\text{KWh consumed in the period}}{\text{hours in the period}} = \frac{(5 \times 1 + 6 \times 1 + 4.5 \times 1 + 5 \times 1) \text{ KWhr}}{(1+1+1) \text{ hr}}$$

$$= 5.13 \text{ KW}$$

Maximum demand/Peak demand: The maximum demand or peak demand of a system is usually expressed as a largest value of demand of the 30 minutes demand during a given period, such as month or year. It may be also instantaneous peak drawn from the source. In the above example 6KW is the peak demand of the system.

Demand factor : The ratio of the maximum demand to the connected load is the demand factor.

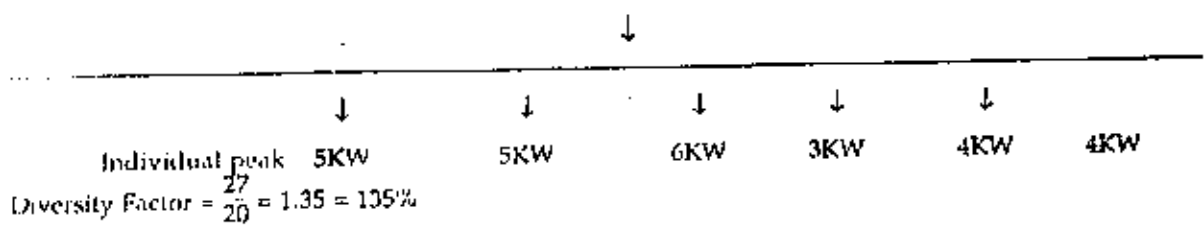
Source 3.5KW (Maximum demand)

↓					
↓	↓	↓	↓	↓	↓
0.5KW	0.5KW	0.1KW	0.2KW	2KW	2KW
Room-1	Room-2	Room-3	Dr. Room	Dinning	Living room
Individual	peak.			room	

$$\therefore \text{Demand factor} = \frac{\text{Peak demand}}{\text{Connected load}} = \frac{3.5}{5.3} = 66\%$$

Diversity factor : This is termed as the ratio of the sum of the individual peak of the system to the maximum demand of the whole system under consideration.

Source 20KW=Peak demand of the whole system.



Load Factor : This is the ratio of average power to the peak demand.

= $\frac{\text{Units consumed in a given period}}{\text{peak demand X hours in the period}}$ Say 4KW, 4.5KW, 4.5KW, 3KW, 2KW, 7KW consumed in 6 hrs.

= $\frac{(4+4.5+4.5+3+2+7) \text{ KWhr}}{(7 \times 6) \text{ KWhr}}$ Here peak demand = 7KW, period = 6hrs.

= $\frac{25}{42} = 0.59 = 59\%$ [Load Factor 1 = optimum use of power.]

2.2.4 Final Selection : Let us Consider a floor of 200Sq. meter.

A Light, Fan TV, VCR, Radio : @ 12 watt/sq. meter
connected Load Total 2400 watt.

First 1000 watt or below considering	D.F. 100% = 1000Watt
Next 500 watt considering	D.F. 50% = 250W
Next 500 watt "	D.F. 33% = 165W
Next 500 watt "	D.F. 20% = 80W

Total = 1495 watt.
Say = 1500 watt.

B. Air conditioner
1 Ton Each is 2 KW
For 4 unit

For First unit considering	100% D.F. 2000watt
For Nerxt 3 unit considering	66% D.F. 3960watt
For more unit considering	33% D.F. Here 000W

Tortal = 5960 watt
Say = 6000watt

C. Water Heater/Kettle
Each load 2 KW

Considering 4 water Heater

For First Unit, considering	100% D.F. 2000watt
For Next 2 unit considering	50% D.F. 2000 watt
For Next Unit, considering	33% D.F. 60watt.

Total = 4660 watt

- D. Refrigerator/Deep Freezer
 10 cft. 140watt each
 For 4 unit
 For First unit considering 100% D.F. 140watt
 For Next 2 unit considering 66% D.F. 278 watt
-
- Total = 418watt.

- E. Water pump
 2 Nos 1/4 H.P.
 Each 186 watt
 Use 50% D.F.
 Total $2 \times 186 \times .50 = 186$ watt.

- F. Other Appliances
 L.S = 200 Watts
 Maximum Demand (Considering Individual Maximum Demand) = 12964 Watts.
 say = 13KW

Considering D.F. among all the circuit as 66% peak Demand of the complex stands at := 8.58 watt
 Say = 9.00 KW

It is the maximum demand. From this demand we are to decide whether the load will be fed by 3-phase or 1-phase system.

Let us calculate the current in both the system, For 3 -phase:-

$$I = \frac{9000}{1.73 \times 415 \times 0.8}$$

$$= 15.67 \text{ Amps}$$

For 1-phase,

$$I = \frac{9000}{230 \times 0.8}$$

$$= 48.9 \text{ Amps.}$$

So, from the amount of current it can be visualized that a single phase supply for the system is uneconomical. the utility should also be taken into consideration.

2.3 Arrangement of Sub-Distribution board circuits.

Circuit No.	MCB(SP) A	Conductor size mm ²	Points
1	10	1.5	6 lighting points 2 ceiling fans
2	10	1.5.	6 lighting points 2 ceiling fans 1 TV socket outlet
3	10	1.5	7 lighting points 1 exhaust fan 1 bell point
4	10	1.5	1 light point first floor and future extension
5	15	2.5	1 air cooler socket outlet.
6	20	2.5	1 air conditioner socket outlet
7	30	4.0	Ring circuit for 5,15A socket outlets.

For multistory buildings, the choice between cables and metal rising main for distribution is made depending upon the load and number of floors to be fed. It is essential to provide separate main circuit for emergency lighting and automatic fire alarm system. Sub-main wiring to each of the flats/apartments/offices should be independent and metered separately. The meter preferably installed at the ground floor.

2.4 CABLE LAYING CONDITION

The basis of current rating in our country has been chosen for normal air temperature of 35°C, and the conditions may be:

2.4.1 Cable in air:

- 1) Ambient temperature 35° C
- 2) One single core cable installed separately free in air or multi core cable installed separately free in air or one 3-P system, comprising single core cables, installed separately free to air in flat formation with a clearance of one diameter between individual single core cables or in trefoil formation each individual single-core cable being in touch with each other.
- 3) One multicore cable, one 3-P system of 3 single core cables installed free in air with minimum clearance of
 - a) 2 cm from floor, wall or roof of the room.
 - b) Twice the cable diameter between two cables and four times the cable diameter between two systems.
 - c) 30cm vertically between layers installed one above the other.
- 4) Cable is protected against radiation of heat from sun or any other source.

2.4.2 Cable in ground :

- 1) Temperature of the soil at the depth of laying = 30°C
- 2) Depth of laying = 91Cm.
- 3) Cable way is covered with layers of sand & brick.
- 4) The cable way is through a pipe length not more then 6(six) meter.

2.4.3 DEVIATED CONDITIONS

If the actual conditions of cable installation are not same as stated, the current rating of cable be multiplied with the rating factors as follows.

- 1) Rating factors for variation of temperature cable laid in air.

Ambient	Temp°C	20	25	30	35	40	45
Rating Factors for cables for	0.6KV & 3.5KV	1.19	1.14	1.07	1.00	0.93	0.85
	5.8KV	1.22	1.15	1.08	1.00	0.91	0.84

- 2) Rating factors for variation to temperature cable laid in underground.

Ambient	Temp°C	15	20	25	30	35	40	45
Rating Factors for cables for	6/3.5 KV	1.18	1.12	1.07	1.00	0.95	0.90	0.84
	10/5.8 KV	1.19	1.14	1.07	1.00	0.93	0.84	0.74

3)	GROUP RATING:	
	<u>Condition of laying</u>	<u>Rating</u>
a)	Cables laid direct in the ground & covered with protective covers for cables.	0.80
b)	Cables laid direct in the ground & covered with protective covers for cables but the space between the cables filled with sand.	0.90
c)	Cables laid in groups	0.75

2.4.4 Necessary checks in cable laying

The cable should be turned/straightend slowly and with longer diameter of a circle as far as possible.

- The H.T. cable should be laid by the side of the road and the L.T. cable should be laid apart from the road when H.T. and L.T. cables are laid side by side.
- When H.T. and L.T. cables are laid in one trench the H.T. cable should be laid under the L.T. Cable.
- The insulation of a cable shall be more thick when it is used in higher voltage rating. The grade of a cable is the highest voltage in which the cable is useable.
- Cable Ends : All stranded conductors having nominal cross sectional area 6mm² and above shall be provided with cable sockets. For stranded conductors of cross-sectional area below 6mm² and not provided with cable sockets, all strands at the exposed ends of the cable shall be soldered together or crimped using suitable sleeve or ferrules.
- Cable joints: Are to be done through porcelain/PVC connector with PIB tape wound around before placing the same in the box. Twisting of conductor may also be allowed if connectors are not available. Cable termination are to be done with lug of adequate size by punching the lugs with punch machine.
- Heat shrink termination and joints in case of cables may be done where specified which is more reliable and safe.

2.4.5 Size of neutral cable/wire : Phase & neutral cable are to be of same size. Making neutral common for more than one ckt. is not allowed. Cables of different colour are used for different phases and neutral wire. Red, Yellow/White, blue colour are for phase wires and black for neutral and green for earth wire.

Earth continuity conductor (ECC) : These are to be of electrolytic annealed copper of 100% conductivity. The same type of copper wire of different sizes shall be used as earthing lead, roof conductor, down conductor, etc.

The Ecc are drawn in the pipes along the cables connecting all metal boxes, such as switch boards, distribution boards, sockets etc. No joint be allowed between the earthing block and respective earth points. Earthing lead shall be connected from the main earthing block up to the earth electrode.

2.5 OVERHEAD LINES FOR INTERNAL DISTRIBUTION

2.5.1 : Installation checks : It shall be checked whether :

- All conductors and apparatus including live parts thereof are inaccessible;
- The type and size of supports are suitable for the overhead lines/conductors used and are in accordance with approved drawing and standards: About 6th of total length of a pole should be placed under ground level.
- Clearances from ground level to the lowest conductor of overhead lines, sag conditions etc. are in accordance with the relevant standard;
- Where overhead lines cross the roads or cross each other or are in proximity with one another, suitable guarding is provided at road crossings and also to protect against possibility of the lines coming in contact with one another.

- The joint of the overhead wires should not lie on the cross arm or clamp.
- The type, size and suitability of the guarding arrangement provided is adequate;
- The vertical gap between two low voltage overhead wires may be from 254 mm to 257 mm (10" to 1'-6"), but the horizontal separation should not be less than 228.6 mm.
- Stays are provided suitable on the overhead lines as required and are efficiently earthed or provided with suitable stay insulators of suitable voltages;
- There should not be more than one joint in a section/span of a wire.
- Joint should be avoided on railway river and road crossing;
- Jointing in the middle of a span of wire should be avoided as far as possible;

Table - 7
Minimum Height of conductors in over head lines

Voltage	Minimum Height	Remarks (Temperature 122°F)
Less than 650V d.c. or 325V, a.c.	5.8m (19')	Across public road
	5.2m (17')	Other positions
	4.6m (15')	Inaccessible to vehicles
Less than 66 kv	6m (20')	
Between 66 and 110 kv	6.4m (21')	
Between 110 & 116kv	6.7m (22')	
Exceeding 165 kv	7m (23')	

- Anti-climbing devices and Danger Board/ Caution Board Notices are provided on all HT supports;
 - The minimum distance between the overhead wire and the ground is 6m when the line crosses or passes over a road;
 - Clearances along the route are checked and all obstructions such as trees/branches and shrubs are cleared on the route to the required distance on either side;
 - The minimum horizontal distance of a lowvoltage over head line is 1.22 meter from a house/building when it is run by the side of a house/building;
 - The minimum vertical clearance of a low voltage over head line is 2.44 meter from a house/building when it is run over the roof of a building;
 - Clearance between the live conductor and the earthed metal parts are adequate;
 - The angular distance between the stay wire and the pole shall be 45° and not less than 30°;
 - For the service connections tapped-off-from the overhead lines cut-outs of adequate capacity are provided;
 - The maximum span between the pole of the distribution overhead line and the service bracket of a house/building is not more than 35 meter (115');
- The following jointing methods may be followed :
- Britania joint
 - Married joint
 - Sleeve joint
 - Compression joint/splice joint

Conductor Arrangement and Spacing

The arrangement of conductors in over head lines may be horizontal, vertical or delta shape

2.5.2 Maintenance of overhead line: The following checks should be done regularly :

- Condition of the pole - It should be checked whether (1) The pole is straight, (2) Cross-arm is in proper position & straight, (3) sufficient earth is there in bottom of the pole, (4) there is any crack in the pole foundation, (5) anti-climbing devices are alright.
- Condition of wires : It should be checked whether (1) anything is falling on or hanging from this overhead wires, (2) The wire has been cut or torn any where (3) any strand of the wire has been cut or torn any where, (4) sag of all the wires are same and alright.
- Condition of insulators : It should be checked whether (1) insulator has been broken, cracked or sign of burning (2) pin is straight and tight, (3) the insulator is cleaned, no sand and dirt, (4) nut-bolts of the insulators are tight.
- Condition of Earthing : It should be checked whether (1) the earthing is properly connected with the pole, earth wire is torn/cut (2) the cradle guard and other devices are properly earthed.
- Condition of lightning Arrestor : It should be checked whether (1) porcelain is cracked or broken, (2) Arcing horn is burnt, (3) the clearance of the horn-gap is proper, (4) the earthing lead is properly connected and alright.
- Condition of other devices/accessories: It should be checked whether (1) there is any defect in line clamps, sleeve etc. (2) nut-bolts are loose, (3) stays are alright.
- It should be checked whether trees and arms of the trees are touching the overhead wires, growing dangerously near/under the over head line. Buildings, houses & other things are about to touch the over head lines.

2.6 EARTHING

The object of an earthing system is to provide a system of conductors, as nearly as possible at a uniform and Zero, or earth, potential. The purpose of this is to ensure that, in general, all parts of equipment and installation other than live parts shall be at earth potential, thus ensuring that persons coming in contact with these parts shall also be at earth potential at all times.

- 2.6.1 Circuit and system earthing is to limit excessive voltage from line surges, from cross-overs with higher voltage lines, or from lightning, and to keep non current carrying enclosures and equipment at Zero potential with respect to earth. Earthing the system helps facilitate the opening of over current protection devices in case of earth faults. All the appliances with metal body connected to the electrical system must be earthed properly to make the system safe and sound to human life.

The normal practice in the country except light fittings ceiling fans, some domestic appliances and office equipment, all metal boxes, switch boards, distribution boards, major equipment etc. are to be earthed properly with adequate size of earth continuity conductors and earthing leads.

2.6.2 Details of earth electrode

The earth electrodes are generally G.I. pipes minimum of 3 meter (10') long, 38.1mm (1.5") dia with 6.35mm (.25") dia several holes on the pipe surface, are driven underground by tube well sinking method upto 6096mm (20') to 2438.4mm (80'). The earthing lead is connected with the earth electrode by copper/brass nut bolts. The earthing lead can either be of copper wire or copper strip. The minimum distance between two electrode(bore) is 3 meter(10'). The earthing lead is protected by 12.7mm ($\frac{1}{2}$ ") dia G.I. pipe upto plinth of a building run at a depth of 610mm below G.L. See Figure.

The resistance of the earth electrode must not exceed 5 ohms.

- 2.6.3 Methods of Earthing : The usual method of earthing is to join the exposed metal work to earth via an earth continuity conductor connected to an electrode buried in the ground. If a live conductor accidentally comes into contact with an exposed metal, the fuse or protective device operates. This cuts off the supply and isolates the faulty circuit, preventing risk of shock, fire, or damage to equipment installation.

Three main elements required for an earthing system are (i) earth conductor (ii) earthing lead (iii) earth electrodes. The details of a bore earthing system are shown in the picture.

Poor connections of earth wire, earthing lead and earth electrodes will render the earthing system ineffective.

The earth electrode should be driven underground at a distance of 1.5m(minimum) from the wall of the bldg.

Where the earth conductor is to be buried under ground in corrosive soil, use of insulated cable as earth conductor is to be preferred. In case of copper wire being used as earth conductors, the size of the ECC shall not be less than half the cross-sectional area of the largest current carrying conductor supplying the circuit.

Minimum cross sectional area of copper earth conductors in relation to the Area of Associated phase conductors are furnished in Table - 8.

The leakage current should not exceed $1/5000$ X full load current of an electric installation.

The following metallic things are to be bonded with ECC for earthed : Bath Tab, metallic pipe, water tank, all other metallic bodies in kitchen, bath room scullery, laundry, milking shed etc. metallic parts of crane, lift etc.

The following types of earth electrodes are recognised.

1. Copper rods
2. Galvanized iron pipes

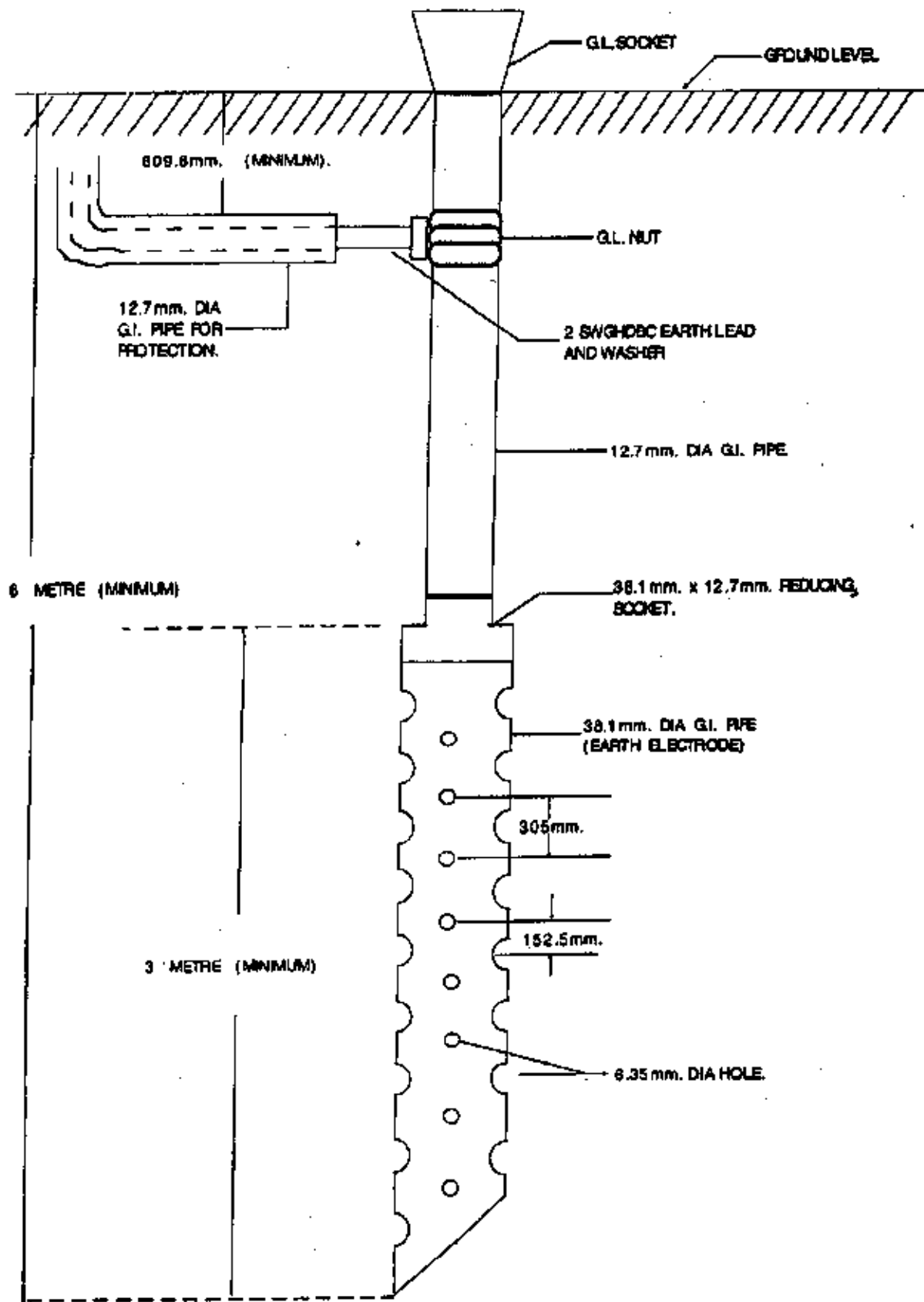


FIG. NO.-10 PIPE EARTHING

Table - 8

Minimum Cross-sectional Area of Copper Earth conductors in Relation to the Area of Associated Phase Conductors.

Cross-sectional Area of Phase Conductors(s) (mm ²)	Minimum Cross-sectional Area of the Corresponding Earth Conductor
(1) Upto 6	(1) Minimum Cross-sectional Area of phase conductor but not less than 14swg.
(2) For 10	(2) 12 swg.
(3) For 16	(3) 10 swg.
(4) For 25 to 35	(4) 8 swg.
(5) For 50 to 75	(5) 6 swg.

2.7 **Testing of installation :** Testing of electrical installation are carriedout before commissioning of the system. Those tests whichd can be carriedout during installation are:

- Continuity test of wiring
- Polarity test of switches
- Insulation test between two conductors of the wiring

Those test which can be carriedout on completion work are :

- : Insulation resistance test between conductor & earth.
- : Earth resistance test.

2.7.1 **Polarity test of switches :** It is carried out with an insulation testing megger. The test is carried out with the switch at 'On position' without lamp in place. One terminal of the megger is connected to switch terminal & another is grounded. If the pointer of the megger indicates zero position the polarity of the switch is considered alright, otherwise the switch is connected to the neutral or some other wire.

Polarity Test of Single Pole Switches (With Insulation Testing Megger) if There is no electricity in The house). (See Figure 11)

Procedure :

Connect first the live line with the Earth in the main switch. Disconnect the load from the switch on Test. Make ON (close) the switch 'On Test'. Connect one terminal of the Megger with the Earth wire and another terminal with any one terminal of the switch 'On Test'. Turn the Megger & record the result. If the switch is installed on the live line the result will be zero. If the result is infinity or some high resistance, then it is sure that the switch is not on live line, the polarity is not correct.

Polarity Test with test lamp (if there is electricity in the house) See Figure 12.

2.7.2 **The continuity test of wirings :** It is carried out with an insulation testing megger. The test is carriedout with two terminals of the megger connected to the two ends of the cable under test and if the pointer indicate zero position the continuity of the cable is confirmed.

2.7.3 **The insulation resistance of wiring :** between phase and neutral, between the phases are measured by the insulation testing megger. All lamps & loads are taken out, all the switches ON, the ends of the cables are taken out from the main control switch and the megger is connected between two wires line to line or line to neutral. On turning the handle the megger will show result in terms of megohm. If the result is more than a specified value the insulation of wiring is considered to be acceptable. If it is lower than the specified level it is considered that in some section there is leakage, which to be foundout by following the same test procedure in different section of the system.

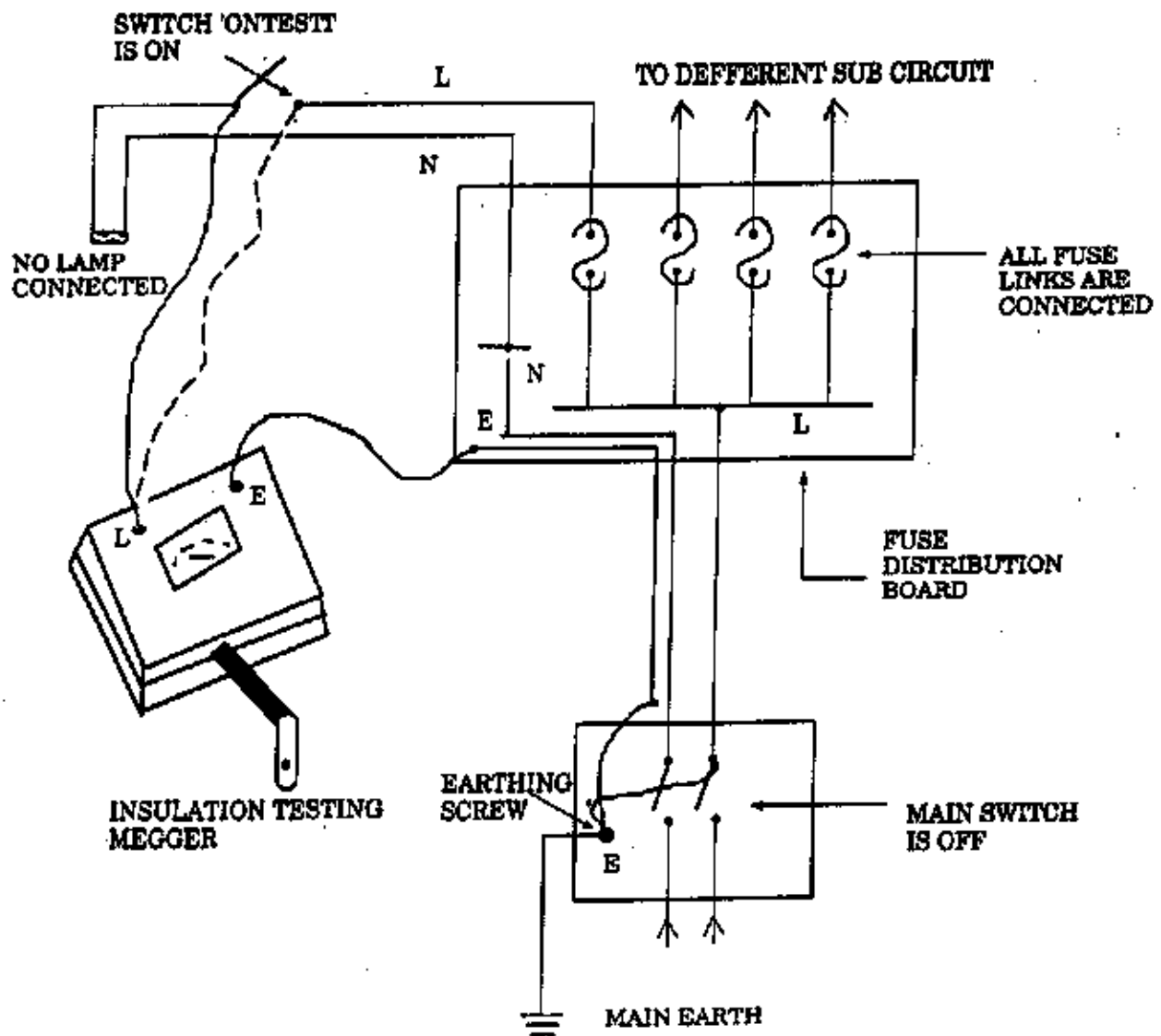


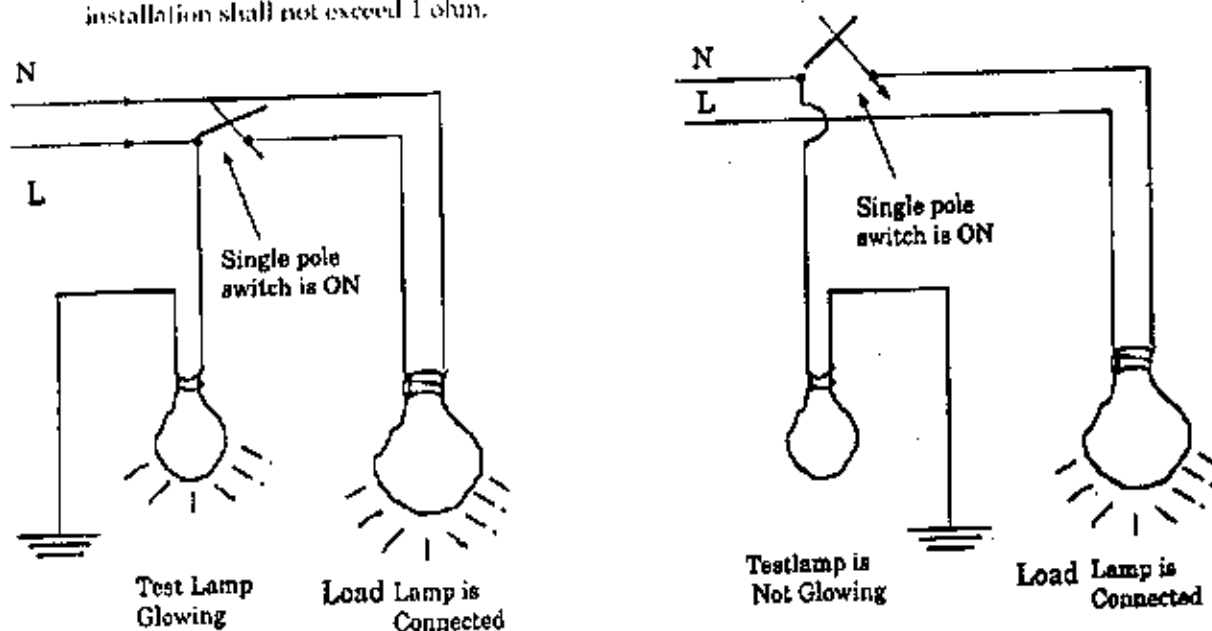
Fig-11

- 2.7.4 Insulation resistance test with earth :** All loads are connected with the system, all switches are ON, main switch is OFF. One terminal of the megger is connected to the main earth of the bldg, other terminal to individual cable end of the load side of the main switch one after another. On turning the handle the megger will show some result, if it is more than a specified value it is acceptable, otherwise the test will have to be done in different section. The minimum acceptable insulation resistance value is 5 megohms. The 500V. megger to be used on ckts under 230V. & 1000V megger to be used for ckts under 230V to 400V.

Before making connections at the ends of each cable run, the insulation resistance measurement test of each cable shall be made. Each conductor of a multicore cable shall be tested individually to all other conductors of the group and also to earth. If insulation resistance test readings are found to be less than the specified minimum in any conductor, the entire cable shall be replaced.

- 2.7.5 Earth resistance test :** It is done by earth resistance tester. Main earth terminal is taken out from earthing block and is connected to earth point of the tester. Two Temporary earth electrodes are connected to the P & C point of the tester. The temp. earth electrodes are about one metre long and (generally) placed along a line at a distance of 20-25 metre and 40-50m from the earth electrode under test. On turning the handle the tester will show some reading which should be less than the specified value, otherwise the earth electrode should be driven more down or an additional electrode is to be added.

The electrical resistance of earth continuity conductor together with the resistance of the earthing lead measured from the connection with the earth electrode to any other position in the completed installation shall not exceed 1 ohm.



Connection No.-1.

In this case the switch is on live line, the polarity is correct.

Connection No.-2.

In this case the switch is on neutral line, the polarity is not correct.

Fig-12

INSULATION RESISTANCE TEST TO EARTH AFTER COMPLETION OF WIRING : See Figure 13

Procedure :

All loads (Fans, Lamps etc) are connected. All fuse links are connected. Main switch is OFF and its fuse links are taken out. All single pole switches are ON (closed) connect the 'E' terminal of the 500 Volt Megger with the Earth screw and 'L' terminal with the live line in the Mains switch (upper part of the user base). Turn the Megger and record the Test result. Again connect the 'L' terminal of the Megger with the neutral terminal of the main switch. Turn the Megger and record the result. The result should not be less than 50 divided by total load points, i.e. it is desirable to get the result more than 1(one) Megohm.

Where more than one earthing sets are installed, the resistance between two sets shall not exceed 1 ohm.

2.8 ELECTRICAL SERVICES, SHAFT AND CONTROL ROOM.

2.8.1 Services Shaft : For high-rise buildings there shall, in general, be a minimum of one vertical shaft of 200mm x 400mm size for every 1500m² floor area. The electrical shaft shall exclusively be used for the following purposes and shall have free access for operation and maintenance.

- electric supply feeder cables or rising mains
- telephone and intercom, fire alarm and signal cables etc.
- area fuse/mini circuit breakers, sub-distribution boards for individual floors, if necessary.

Bus Ducts.

2.8.2 a) Bus ducts are specially useful to minimize voltage drop on account of high-amperage intermittent loads. The conductors supported by insulators inside the bus duct may be of copper or aluminum of solid, hollow or rectangular cross section. The conductors may also be insulated. Bus ducts should

be used for exposed work or where concealing is not of a permanent nature. The bus duct shall be laid with minimum number of bends for distribution system. Typical rating of feeder bus ducts for 3-phase, 3 wire or 4 wire system shall range from 200 amperes to 3000 amperes.

- b) Concrete horizontal ducts of suitable size shall be provided along the roads for a group of buildings to be fed by a single sub-station.

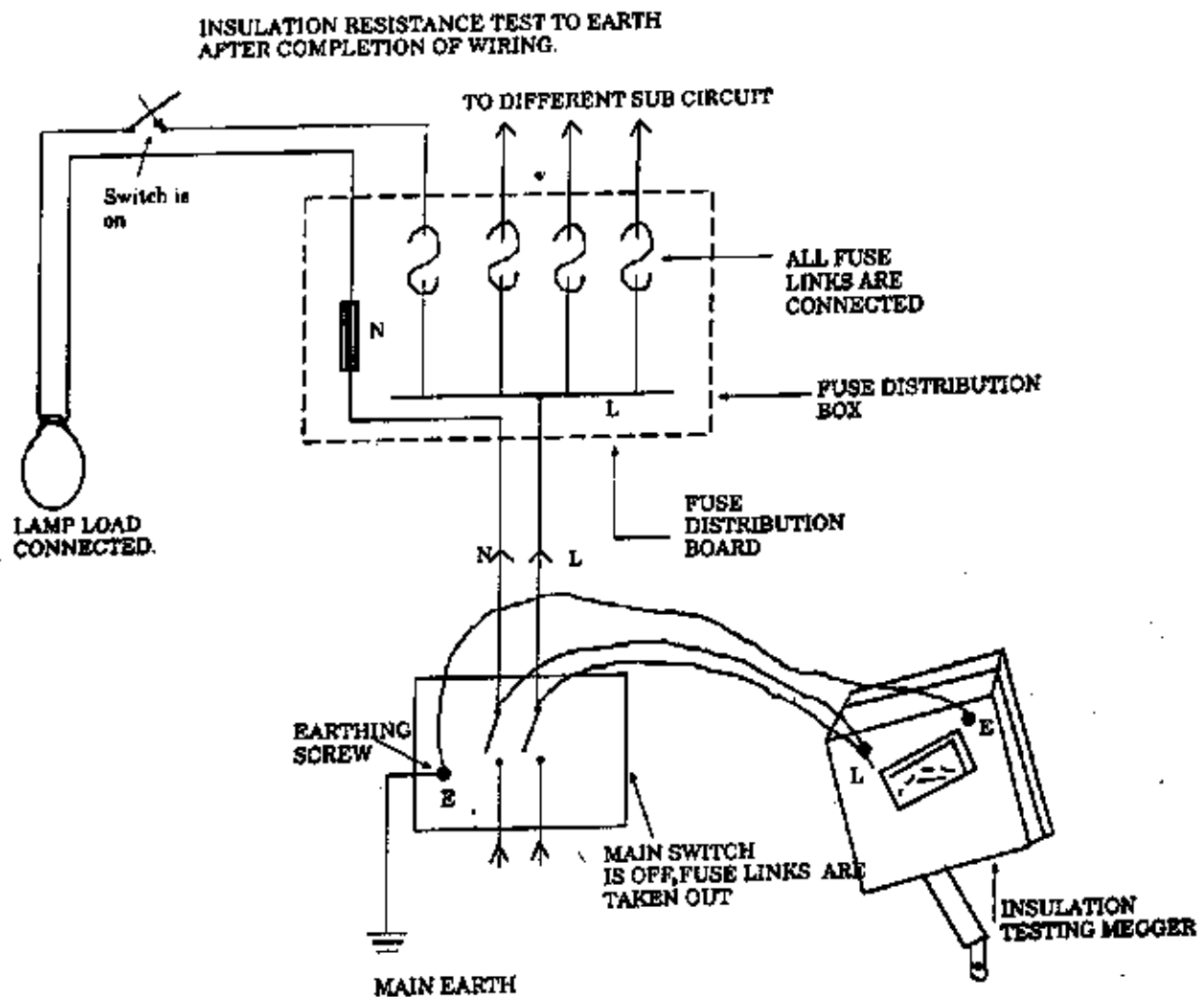


Fig - 13

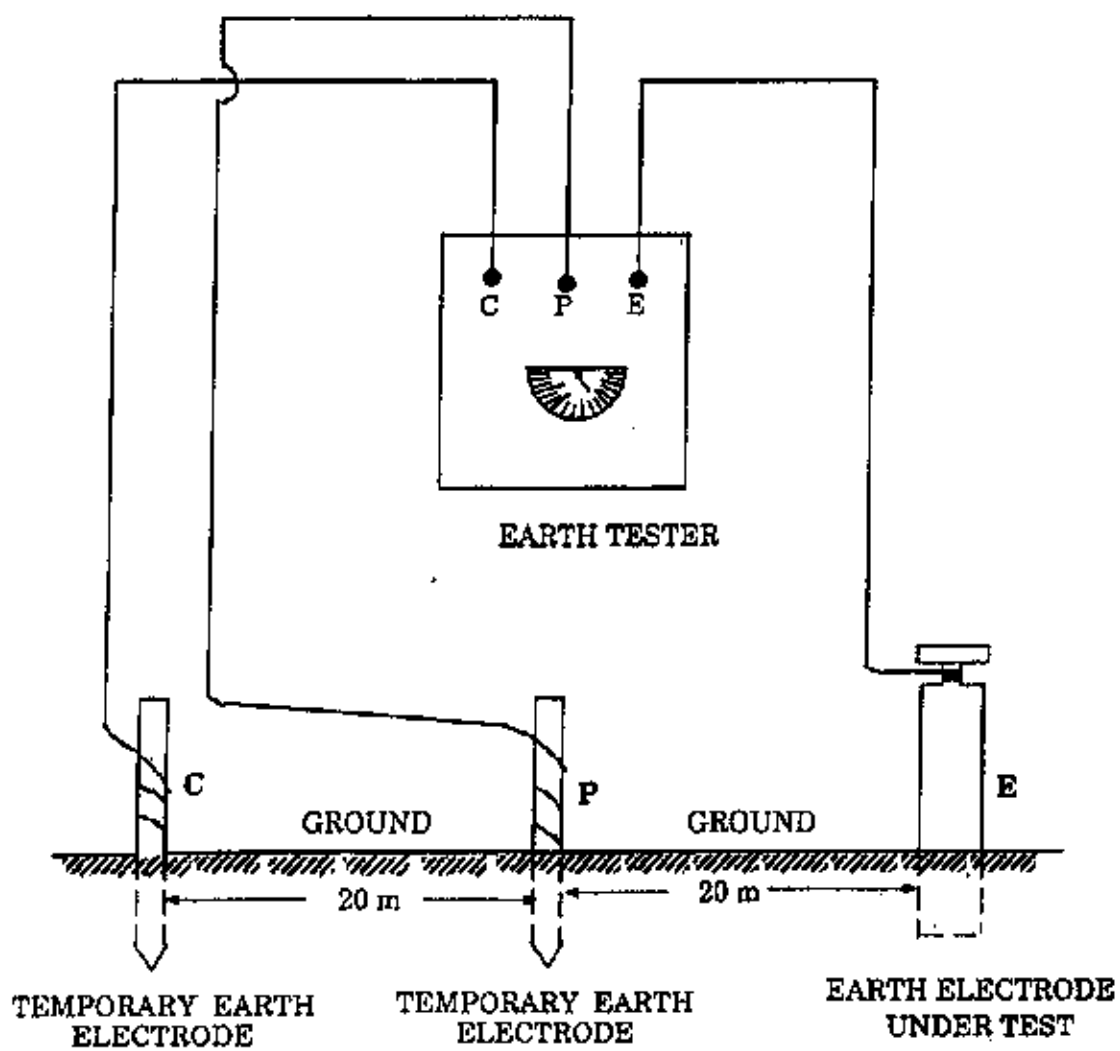


FIG. 14 EARTH RESISTANCE TESTING

2.8.3 ELECTRICAL CONTROL ROOM

For high rise buildings there shall in general be an electrical control room of 8'x6' size in each floor attached to the bus duct/Electrical services shaft. This control room shall exclusively be used for electrical control panel/control accessories, electricians/attendants etc. for each floor.

For Hospitals, bldgs of larger floor area there shall be one main electrical control room in the ground floor (in addition to the sub-station room) of size 10'x8' for the purpose as mentioned above.

More than one bus duct, service shaft may be provided for large floor area and high rise buildings.

- 2.9 Protection of Ckts: Appropriate protection shall be provided at switch boards and distribution boards for all ckts and sub-ckts against short ckts and overcurrent and the protective device shall be capable of interrupting any short ckt current that may occur, without danger. The ratings and settings of fuses and the protective devices shall be co-ordinated so as to afford selectivity in operation.

Where ckt breakers are used for protection of main ckt and the sub-ckts derived there from, discrimination in operation shall be achieved by adjusting the protective devices of the sub-main-ckt breakers to operate at lower current settings and shorter time lag than the main ckt breaker.

A fuse carrier shall not be fitted with a fuse element larger than that for which the carrier is designed.

The current rating of fuses shall not exceed the current of the smallest cable in the ckt protected by the fuse.

- 2.10 System of supply : All electrical apparatus shall be suitable for the voltage and frequency of supply. It is 230V, 50Hz, single phase, or 400V, 50Hz, three phase.

The number and type of live conductors (e.g. single phase two wire a.c. three phase four-wire a.c. etc) shall be assessed both for the source of energy and for the ckts to be used within the installation.

The following characteristics of the supply shall be ascertained :

- Nominal voltage(s)
- Nature of current and frequency
- Prospective short ckt current at the origin of the installation
- Type and rating of the over current protective device acting at the origin of the installation
- Suitability for the requirements of the installation including the maximum demand
- Expected maximum value of the earth loop impedance of that part of the system external to the installation.

The voltage is categorised in the following way:

Extra low voltage	:	not more than 60volt
Low voltage	:	not more than 250volt
Medium voltage	:	not more than 650volt
High voltage	:	more than 650volt.

- 2.11 Lightning protection of bldg : Whether a building needs protection against lightning is a matter of judgment on the part of the designer.

A complete lightning protection system consists of air termination net work, a down conductor and an earth termination. The air termination network is that part which is intended to intercept lightning discharges. It consists of vertical and horizontal conductors arranged to protect the required area.

Height of the structure is an important factor for the purpose of lightning protection. Taller structures are subject to greater hazards than smaller structures and therefore, lightning protection is more desirable for tall structures.

- 2.11.1 The number of arrestors required & their installation :

All building above three storied should have lightning protection system. The air terminal is to be located at the highest point of the bldg. One air terminal covers an area of about 15.25m x 15.25m (50'x50'). If roof area of a bldg. is more than 15.25m x 15.25 m (50'x50') more than one air terminal is

to be provided. All the air terminals are connected together with roof conductor and to be grounded through down conductor.

The earth termination is that part which discharges the current into the general mass of the earth. In other words, it is one or more earth electrodes. Earth electrodes for lightning protection are no different from earth electrodes for short ckt protection system.

The total resistance of an electrode for a lightning protection system must not exceed 10 ohms.

The materials used for lightning conductors must be aluminium or copper. The criterion for design is to keep the resistance from air termination to earth to a minimum.

Recommended dimensions for various components are given in table 12. Larger conductors should however be used if the system is unlikely to receive regular inspection and maintenance.

Table - 9
Sizes of the Components of Lightning protection Systems

Components	Minimum Dimensions
Air Terminations	
Aluminum and copper strip	20mm x 3 mm
Aluminum, aluminum alloy; copper and phosphor bronze rods	10mm dia
Stranded aluminum conductors	19 strands of 2.5mm
Standard copper conductors	19 strands of 1.8mm
Down Conductors	
Aluminum and copper strip	20mm x 3mm
Aluminum, aluminum alloy and copper rods	10mm dia
Earth Terminations	
Hard drawn copper rods for driving in to soft ground	12mm dia
Hard drawn or annealed copper rods for indirect driving or laying in ground	10mm dia
Phosphor bronze for hard ground	12mm dia
Copper clad steel for hard ground	10mm dia

The down conductor is the conductor which runs from the air termination to the earth termination. A building with a base area not more than 100m² needs only one down conductor. For a larger building there should be one down conductor for the first 100m² plus a further one for every 300m² or part there of in excess of the first 100m². Alternatively, for a larger bldg one down conductor may be provided for every 30m of perimeter.

External metal on a building should be bonded to the lightning conductor with bonds at least as large as the conductor.

The Zone of protection is the space within which a lightning conductor provides protection by attracting the stroke to itself. It has been found that a single verticle conductor attracts to itself strokes of average or above average intensity which in the absence of the conductor would have struck the ground within the circle having its centre at the conductor and a radius equal to twice the height of the conductor. For weaker than average discharges the protected area becomes smaller. For practical design it is therefore assumed that statistically satisfactory protection can be given to a Zone consisting of a cone with its apex at the top of the verticle conductor and a base radius equal to the height of the conductor. This is illustrated in figure.

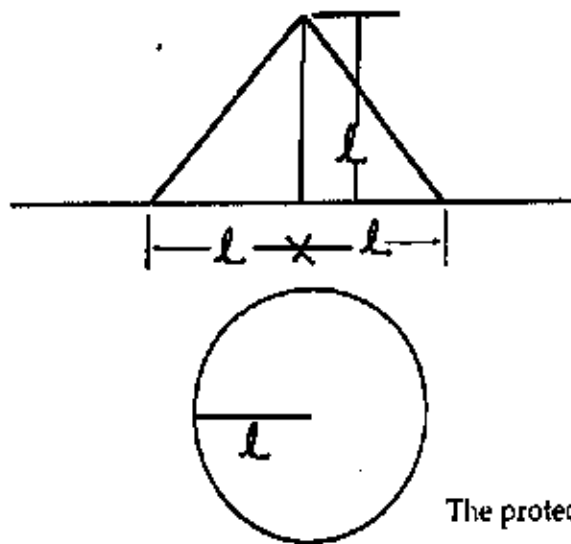


Fig - 15

2.11.2 Surge arester selection : Surge arrester is a protective device for limiting surge voltages by discharging, or by passing, surge current through it, it also prevents continued flow of follow through current while remaining capable of repeating these functions. It is used to protect overhead lines and other electrical apparatus, viz. transforming from overhead voltages and lightning.

Horn gap lightning arrestors are commonly used for low and medium voltage overhead lines. The rating of the surge arrester shall be equal to or greater than the maximum continuous phase to ground power frequency voltage available at the point of application.

When a lightning conductor carries a stroke to earth, it is temporarily raised to a potential considerably above that of earth. There is therefore, a risk that the discharge will flash over to nearby metal and cause damage to the intervening structure. This can be prevented by either providing sufficient clearance between conductor and other metal or by bonding these together to ensure that there can be no potential difference between them. The necessary clearance is obtained from :

$$D = 0.3R + \frac{H}{15n}$$

Where

- D = clearance in metres
- R = resistance to earth in ohms
- H = height of building in metres
- N = number of down electrodes

Since it is often impracticable to provide the necessary clearance, the alternative technique of bonding is to be preferred.

2.12 TELE COMMUNICATION AND MISCELLANEOUS SERVICE

Telecommunication ckts : Telephone cables are quite small and if the position of the outlet for the telephone receiver is known it is sufficient to install a 20mm conduit from outside the bldg to the outlet, with the same number and spacing of draw in points as are used for any other conduit system. Some buildings may have an internal telephone system which may consist of extensions to the public telephones or may be an entirely separate installation. Here again the essential matter for the eslectrical services designer is to agree on the outlet positions with his customer and to arrange for them to be linked to each other by conduit or trunking. Telephone cables do not have a protective sheath and therefore need the mechanical protection of conduit or trunking. Where practicable, a seperation of at lerast 1.8m shall be maintained between open conductor of communication systems on building and the lightning conductors.

T. V. Antenas : it is an advantage to receive Television or radio signals at one suitably sighted antena array and relay them to individual dwellings by cables or transmission lines. Lead in cable must be installed with care to prevent damage to the cable.

Where practicable, a separation of at least 92m is to be maintained so as not to change the spacing of the conductors with the cable. Such changes result in a distorted television signal. Shielded lead in cable may be run in or near metal objects without affecting television reception. Un shielded lead in wires installed closed to these items may affect reception.

- 2.13 Operating Test : Current load measurement shall be made on equipment and on all power and lighting feeders. The current reading shall be taken in each phase and in each neutral wire while the ckt or equipment is operating under actual load conditions. Clip-on ammeters may be used to take current readings. All light fittings shall be tested electrically and mechanically to check whether they comply with the standard specifications. Fluorescent light fittings shall be tested so that when functioning no flickering or choke singing is felt.

2.14 ELECTRIC SHOCK AND HAZARD

- 2.14.1 General idea : If the frequency of the voltage is very low, then the body of a person can bear 1mA to 8 mA current flow through his body. The shock is very severe if it is 8mA to 15A. The shock stops the respiration function of a person when the current flow is from 20mA to 50mA through the body and damages the heart when it is 100mA to 200mA. The body of a person burns when the shock is of above 200mA.

The resistance in a dry body of a person varies from 70 Kohm to 100 K.ohm. But in a wet body it reduces to 700 ohm to 1000 ohm.

The more is the leakage current from a wire/cable/electrical equipment/electrical appliances the severior is the electric shock.

- 2.14.2 Necessary checks : The earth continuity wire should be checked for its continuity and jointing/bonding with the earth terminal in switch box, junction box, earth electrode, earth terminal etc. as well as the perfectness of the earthing system for safety from electric shock.

It should be checked that, the switch is connected with the live line of the ckt, not with the neutral wire to remain safe from electric shock.

There remains some electrostatic charge after switching off in high voltage overhead line, transformer, condenser, etc. which may occur electric shock to a person.

- 2.14.3 Precautions to work with electric wires, Lines, installations to avoid accident due to electric shock :

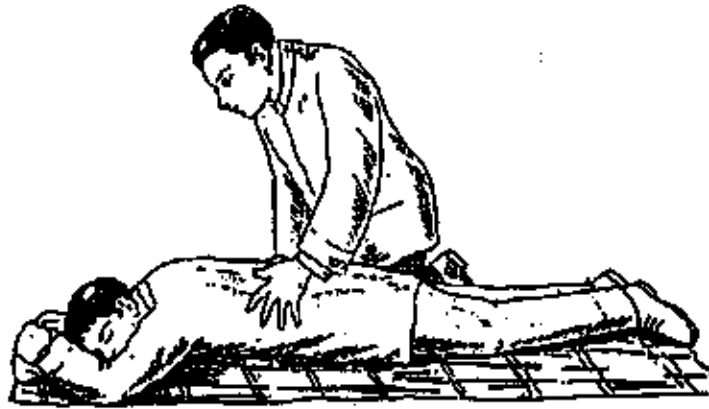
- Test should be done whether the conductor is live by touching it with Neon-Tester or by testing it with a Test lamp, touching one end of the wire of the Test lamp with the live conductor and another end with the earth wire. (In case of low and medium voltage).
- The ckt or section of a wiring where the insulation resistance is less than 1mega ohm should be replaced by new wire.
- The terminals of any high voltage line or equipment should not be touched just after switching off the line/ckt. After switching off, the line/terminal should be discharged to an earth by touching with a piece of high voltage insulated cable, both end of which is terminated.
- Power out lets of all house hold electric appliances such as oven, calender, heater, radio, T.V. VCR, conker, washing machine, Hair drier, Vacuum cleaner, etc. should be properly Earthed.
- Instruction both in English and in Bengali for the restoration of sufferings from electric shock, shall be affixed by the owner in a conspicuous place in every generating station and sub-station and other premises where electricity is used.

2.14.4 Measures after getting shock

The following measures should be taken to save the life of a person after getting electric shock.

- The main switch/or the particular switch should be switched off immediately, the person getting shock should be detached from the electric line/equipment/appliances with the help of a dry wood piece, bamboo piece or by pulling him after rapping dry clothings, blankets or pulling by wearing rubber hand gloves etc, but should never be touched with bare hand before switching off the line/ckt completely. Rubber shoes be weared by the person who is detouching the body under shock.

Fig : 16



Position No.-1
Pressing by Palm on the Back



Position No.-2

- b) After detouching the body under shock artificial respiration should be started. The patient should be laid down as shown in the picture immediately after detouching from the electric line or equipment. The process of pressing the patient slowly by the help of two palms with full weight of the body on the back of the patient (starting from position No.1 to position No.2) and releasing the pressure should be started. Repeat it 15 times per minute. Continue the process upto 2/3 hours till the doctor comes.
- c) The patient should not be tried to drink/eat any thing when he is in senseless condition.
- d) The body of the patient should be warmed up.

2.14.5 Instructions

The following instructions should be carried out to avoid electrical hazards :

- a) All circuit breakers and the fuse wires of the main switches/BDB/SDB/MDB etc. should be of accurate ratings.
- b) Fuse wires, not ordinary wires, should be used in the main switches/control switches.
- c) The load should be almost equally distributed among the phases and the circuits.
- d) The fuse wires should be installed with a fuse cutout (grip fuse, totally enclosed fuse or cartridge fuse)
- e) 3-pin power outlets should be of interlocked and earth connected properly.
- f) Wiring should be done through surface pipe or in concealed manner in kitchen, workshop etc.

- g) Fire fighting equipment, sand filled bucket, water filled bucket etc. should be kept in front of the entrance of a house or in the stair case or in each floor's corridor of the building.
- h) Two to three inmates of a house should know the restoration of suffering from electric shock.
- i) Proper training should be taken to use the fire fighting equipment.
- j) The main switch of a house should immediately be switched off when an electrical accident occurs.
- k) Electrical Advisor and chief electrical inspector should be informed within 5 hrs of occurrence of electrical accident.
- l) No electrical installation work including additions, alterations, repairs and adjustments to existing installations, except such replacement of lamps, fans, fuses, switches and other component parts of the installations as in no way alters its capacity or character shall be carried out upon the premises or on behalf of any consumer or owner except by an electrical contractor licensed by government in this behalf and under the direct supervision of a person holding a certificate of competency issued by the government.

2.15 NECESSARY CHECKS IN ELECTRICAL INSTALLATION

The lighting circuits shall be checked to see whether :

- Wooden boxes and panels are avoided in workshops or factories for mounting the lighting boards and switch controls, etc.
- Neutral links are provided on double pole switch which are used for lighting control, and no fuse is provided in the neutral.
- The plug points in the circuit for appliances are all 3-pin type, the third pin being suitably earthed.
- Tamper-proof interlocked switch socket and plug are used for locations easily accessible.
- A separate earth wire is run in the lighting installation to provide earthing for plug points, fixtures and equipment.
- Proper connectors and junction boxes are used wherever joint are to be made in conductors or cross over of conductors takes place.
- Cartridge fuse units are fitted with cartridge fuses only.
- Clear and permanent identification marks are painted in all distribution boards, switch boards, sub-main boards and switches as necessary.
- The polarity has been checked and all fuses and single pole switches are connected on the phase conductor only & wiring is correctly connected to socket-outlets.
- Spare knockouts provided in distribution boards and switch fuses are blocked.
- The ends of conduits enclosing the wiring leads are provided with ebonite or other suitable bushes.
- The fittings and fixtures used for out-door use are all of weather-proof construction & similarly, fixtures, fittings and switch gears used in the hazardous area are of flame-proof application.
- Proper terminal connectors are used for termination of wires (conductors and earth leads) and all strands are inserted in the terminals.
- Flat ended screws are used for fixing conductor to the accessories
- Flat washers backed up by spring washers are used for making end connections.
- The energy meter installed gives over-reading, the reasons are :-
 - a) The position of the permanent magnet is shifted apart from the centre of the disc.
 - b) The supply voltage is very high, the position of magnetic field is haphazardly, the position of the shunting bend is not proper, the meter revolves without load.
 - c) There is earth fault in between the switch and the meter, and the meter revolves without load.

2.16 Inspection of the installation : On completion of wiring a general inspection shall be carried out by competent personnel in order to verify that the provisions of this book of specification and that of the electricity act of Bangladesh have been complied with. A completion report as furnished below may be submitted on satisfactory completion of the work in which all the important informations will be recorded.

2.16.1 Contractor's work supervision : The work done by the contractors should be supervised properly. A good design and planning will never give a good result if it is not implemented properly. Wire connection by twisting or wrapping shall be avoided, instead, cable lugs should be fixed. Single Pole switches shall not be connected in the neutral wire. It is a very common mistake by the electrician. Screwing of conductor connection through lugs shall be tightened, otherwise increase of heat due to increased resistance will damage the system. The connection of earthing with the neutral and appliances shall be checked. The burying of electrode as per design, the points which are unsighted should be checked. Ironically, in electrical system the unsighted things are more dangerous and fatal accidents start from those points.

A contractor shall be well equipped for the works. Before starting the work, a check list for the tools shall be done.

The contractors must have valid contractor's license for execution of electrical works and also have licensed personnel at project site with proper tools and appliances to execute the work in orderly manner. The licensed personnel are technicians with workman's permit and supervisors with electrical supervisor's certificate of competency of required class. The classes of work are A, B & C. A license holder having A, B & C class is entitled to work upto any voltage level while one having B & C class, entitled to work upto voltage level of 650 volt and only C class license holder can work upto voltage level of 250volts.

2.16.2 Completion Report : A completion report should be prepared after completion of the wiring/installation work as furnished below:

It is reported that the installation work detailed below has been completed by the contractor, tested & supervised by me/us and that to the best of my/our knowledge and belief, it complies with specification of PWD & general standards

Electrical Installation at _____

Voltage and system of supply _____

A. Particulars of works :

a) Internal Electrical Installation :

Number of	Number of light Fittings with name.	Type or system of wiring:
i) Light point	i)	
ii) Fan point	ii)	
iii) Plug point	iii)	
3-pin 5A	iv)	
3-pin 15A	v)	

b) Others

Description hp/kw/kva/Type	Type of starting
1) Motors	
i)	
ii)	
iii)	
2) Other plants/equipment	

c) If the work involve installations of overhead line and/or underground cable.

- 1) i) Type and description of over headline
- ii) Total length and no. of spans
- iii) No. of street lights and its discription

- 2) i) Total length of underground cable and its size
- ii) No. of joints: (cable wise) Size
- iii) End joint " "
- iv) Tee joint " "
- v) Straight through joint " "
- vi) Plan with cable route and cable joints : Enclosed

d) Earthing

- i) Description of earthing electrode
- ii) No. of earth electrodes
- iii) Size of main earth lead

B. Test Results

a) Insulation Resistance

- i) Insulation resistance of the whole system of conductors to earth Megaohms
- ii) Insulation resistance between the phase conductor and neutral
 - Between phase R and neutral Megaohms
 - Between phase Y and neutral Megaohms
 - Between phase B and neutral Megaohms
- iii) Insulation resistance between the phase conductors in case of poly phase supply.
 - Between phase R and phase Y Megaohms
 - Between phase Y and phase B Megaohms
 - Between phase B and phase R Megaohms

b) Polarity test

Polarity of non-linked single pole branch switches

c) Earth continuity test

Maximum resistance between any point in the earth continuity conductor including metal conduits and main earthing lead Ohms.

d) Earth electrode resistance:

Resistance of each earth electrode

- i) Ohms
- ii) Ohms
- iii) Ohms
- iv) Ohms

e) Lightning protective system

Resistance of the whole of lightning protective system to earth before any bonding is effected with earth electrode and metal in/on the structure Ohms

Signature of S.A.E.
Name and address

Signature of SDE/AE
Name and address

Signature of Contractor
Name and address

NATIONAL & INTERNATIONAL STANDARDS & SPECIFICATIONS

Meanings of commonly used abbreviations and most important testing authorities for approvals.

- ABS - Marine classification society, country, USA.
- ANSI - Publishes specifications & standards for practically all fields of engineering. As regards low-voltage switchgear ANSI has largely adopted the NEMA & UL standards.
- AS - The Australian standards have partly been brought in line with IEC Recommendations.
- BSI - The British standards have partly been brought in line with IEC Recommendations.
- BV - Bureau Veritas - Marine classification society, country - France.
- CEE - International specifications, generally relating to wiring accessories, comprises national electrical committees of 22 European countries.
- CEN - European committee for standardizations, comprises National standards bodies of IEC & EFTA countries with Greece and Spain as correspondent members.
- CEMA - Canadian Electrical manufacturer's Association.
- CENELEC - Comitee Europien de Normalisation electrotechnique : European committee for the co-ordination of electro technical standards Electrotechnical counterpart of CEN. (General secretariate Brussels).
- CSA - Canadian standards Association : Publishes standards & grants approval.
- DEMKO - Danmark Elektriske material kontrol : Danish Institute for Electrical products. It publishes standards and grants approval.
- DIN - Deutsche Industries Normalien : German Industrial standards.
- GL - Germanischer Lloyd Marine classification society, country Germany.
- IEC - International Electrotechnical commission : All large industrial Nations are represented in the International Electrotechnical commission [over 60 countries.]
- ISI - Indian standard Institution : The Indian standards have partly been brought in line with IEC Recommendations.
- CIE - Int. commission of illumination, comprises National illumination committees of 30 countries.
- JS - Japanese Industrial standard : Japanese standards.
- ISO - International organisation for standardization-comprises national standards bodies of 57 countries plus 15 correspondent members.
- KEMA - Keuring van elektrotechnische Materialien : Dutch testing laboratory for Elect. products.
- LRS - Lloyds Register of shipping : Marine classification society, country Great Britain.
- NBN - Norme Belge : Belgian standards, partly brought in line with IEC Recommendations.
- NEMA - National Electrical Manufacturer's Association : Country USA.
- NEMKO - Norges Elektriske Material kontrol : Norwegian institution for electrical products. It publishes standards & grant approval.
- NK - Nippon Kaiji Kyokai : Japanese classification society.
- NV - Det Norske Veritas : Marine classification society, country Norway.
- OVE - Osterreichischer verband fur, Elektrotechnik : The Austrian standards are generally in conformity with VDE & IEC.
- PRS - Poiski Rejestre statkow : Marine classification society, country poland.
- RINA - Registro Italiano Navale : Marine classification society, country Italy.
- SEMKO - Svenska Elektriska Material kontrollan stalten : Swedish institusion for Electrical products.
- SEN - Svenska standard : Swedish standards.
- SEV - Scheveizerischer Elektrotechnischer verein : Swiss Electrotechnical Association.

- UL - Underwriters' Laboratories - They perform tests on elect. products & issue regulations in USA
- UTE - Union technique de Electricite : French Electrotechnical Association.
- VDE - Verband Deutscher Elektrotechniker : Association of German Electrical Engineers.

Standards for Electrical equipment

These standards establish rules for the design of the controls.

1) International recommendations

- IEC 204-1 - Electrical equipment of machine tools.
- IEC 204-2 - Electrical equipment of machine used in large series production lines.
- IEC 204-3 - Electrical equipment of machine tools.
- IEC 56 part 1 to 7 - High voltage A. C. circuit Breakers.
- IEC - 60 - High voltage Test Techniques.
- IEC - 71 - Insulation co-ordination.
- IEC - 157 - Low voltage switch gear and control gear.
- IEC - 158 - Contactors.

2. Federal Republic of Germany

- VDE - 0.113 - Regulation for the electrical equipment of production & processing machines.

3. France

- NFC - 79 - 100 - Electrical equipment of General purpose machine tools.
- NFC - 79 - 110 - Electrical equipment of heavy duty machine tools.
- NFC-79-120 Electronic equipment of machine tools.

4. Great Britain

- BS 2771 - Electrical equipment of machine tools.
- BSCP - 1015 - The Electrical equipment of industrial machines.

5. India

- IS - 1356 - 1 - Electrical equipments of machine tools.
- IS - 1356 2 - Electrical equipment of machine used in large service production lines.
- IS - 1885 - Part X - 1968, Electrical vocabulary
- electrical power system protection.
- IS : 3074 - Part - 1 - 1965 : code practice for Installation and maintenance of switchgear. part - 1 switch gear not exceeding 1000V.
- IS : 5728-1970 : Guide for short circuit calculations.
- IS : 3106-1966 : Code of practice for selection, installation and maintenance of Fuses (Voltage not exceeding 650V)
- IS . 384-1966 : Application Guide for electrical Relays for A.C. systems part - 1 to V.
- IS : 4004 - 1967 : Application Guide for Non-linear lightning Arrestor for A.C. systems.
- IS : 585-1962 : Voltage and frequency for A.C. Transmission and Distribution systems.
- IS : 2165-1973 : Insulation Co-ordination.

6. Italy

- CE : 144-1 - Electrical equipment of machine tools.

Wire Gauges

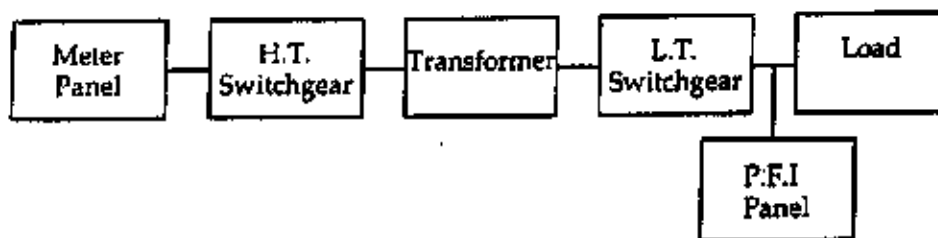
AWG	SWG	Diameter mm	Cross-sectional Area mm ²	Weight of Copper Kg/Km	Weight of Aluminium Kg/Km
6/0	-	14.73	170.46	1515.4	460.4
5/0	-	13.11	134.92	7199.4	365.0
-	7/0	12.70	126.68	1126.2	342.1
-	6/0	11.79	109.09	969.8	294.6
4/0	-	11.68	107.22	953.2	289.4
-	5/0	10.97	94.56	840.7	255.4
3/0	-	10.41	85.16	757.2	229.6
-	4/0	10.16	81.70	720.7	219.6
-	3/0	9.449	70.12	623.4	189.4
2/0	-	9.271	67.51	600.1	182.1
-	2/0	8.839	61.36	545.5	165.7
0	-	8.255	53.52	475.8	144.4
-	0	8.230	53.19	472.9	143.6
-	1	7.620	45.60	405.4	123.1
1	-	7.341	42.22	376.2	114.5
-	2	7.010	38.60	343.1	104.2
2	-	6.553	33.94	299.8	90.80
-	3	6.401	32.18	286.1	86.89
-	4	5.893	27.27	242.5	73.63
3	-	5.817	26.57	236.2	72.01
-	5	5.385	22.77	202.5	61.51
4	-	5.182	21.09	187.5	57.11
-	6	4.877	18.68	166.1	50.44
5	-	4.623	16.78	149.2	45.25
-	7	4.470	15.70	139.5	42.39
6	-	4.115	13.30	118.2	35.91
-	8	4.065	12.97	115.3	35.02
7	9	3.658	10.507	93.41	28.49
8	10	3.251	8.302	73.80	22.59
-	11	2.948	0.818	60.61	18.41
9	-	2.896	6.585	58.54	17.91
-	12	2.642	5.480	48.72	14.80
10	-	2.591	5.272	46.87	14.21
-	13	2.337	4.284	38.08	11.58
11	-	2.311	4.196	37.30	11.26
12	-	2.057	3.325	29.55	8.934
-	14	2.032	3.243	28.83	8.756
13	15	1.828	2.627	23.35	7.093
14	16	1.626	2.075	18.45	5.621
15	-	1.448	1.646	14.64	4.460

-	17	1.422	1.589	14.13	4.290
16	-	1.295	1.318	11.72	3.532
-	18	1.291	1.168	10.38	3.154
17	-	1.143	1.026	9.122	2.808
18	19	1.016	0.8107	7.207	2.223
19	20	0.9144	0.6567	5.838	1.773
20	21	0.8128	0.5189	4.613	1.401
21	-	0.7239	0.4156	3.695	1.111
-	22	0.7112	0.3973	3.532	1.073
22	-	0.6428	0.3243	2.883	0.8756
-	23	0.6096	0.2919	2.595	0.7881
23	-	0.5733	0.2588	2.301	0.6990
-	24	0.5588	0.2453	2.181	0.6620
24	-	0.5105	0.2047	1.820	0.5527
-	25	0.5086	0.2021	1.797	0.5473

ELECTRICAL SUBSTATION

3.1 **General :** The electrical sub-station shall normally be required for a load of 50KVA and above in a building or premises as per prevailing rule of PDB. To arrive at the size of the sub-stations required a load factor of 70% shall be applied to the estimated load of the building/premises, unless future expansion requirements dictate that a higher figure be considered. The transformer upto 250 KVA may be installed on pole or on pad with H.T. disconnector switch, dropout fuse, lightning arrester for controlling of H.T. side.

3.2 **Layout :** The layout in the sub-station should be as shown below:



All the rooms shall be provided with partitions upto the ceiling and shall have proper ventilation. Transformer room should be specially ventilated with louvers at lower level and exhaust fans at higher level in such a way that cross ventilation is maintained.

The minimum height of the sub-station room shall be 3.6m. The minimum area required for sub stations/transformer room for different capacities are given in Table.

3.3 LOCATION

In a multi-storied bldg. the sub-station shall preferably be installed on the lowest floor level, but direct access from the street for installation or removal of the equipment shall be provided. The floor level of the sub-station or switch room shall be above the highest flood level of the locality.

In case of a building complex, or a group of bldgs the sub-station should preferably be located in a separate bldg and should be adjacent to the generator room. Any location of sub-station in the basement floor should be avoided. If the sub-stations has to be located within the main bldg, it should be located on the ground floor with easy access from out side.

For transformers having large oil content, (more than 2000 litres) soak pits are to be provided.

3.4 ADVANTAGE

In case of connected loads of 50KVA and above, the relative advantage of high voltage 3 phase supply should be assessed.

The advantages are :

- Possible advantages in tariff
- More effective earth fault protection for heavy current Ckts.
- Reduction of interference with supplies to other consumers permitting the use of large size motors, welding plant etc. and
- Better control of voltage regulation and more constant supply voltage.

3.5 SHORT DESCRIPTION OF SUB-STATION EQUIPMENT & ACCESSORIES

Transformer - A transformer consists essentially of a magnetic circuit linking with two distinct windings, the primary and secondary. When the primary is connected to an a.c. supply an alternating flux will be setup in the core, and this flux linking with the secondary will induce an alternating e.m.f. in the secondary. The operation can thus be regarded as a case of mutual induction.

There are three windings in primary and secondary side in 3-phase transformers of 3-phase supply system. The windings are rapped on the core made of laminated & specially varnished silicon steel sheet. The windings are of insulated wires/thin foils. The insulation is done by specially made paper or cloths. The windings with the core are submerged into transformer oil in a Tank. In large transformers there are several tubes connected with the body to cool the transformer oil, these are called Radiators. There is a small oil drum above the tank called conservator to facilitate expansion and contraction of the transformer oil when heated & cooled respectively. Silicagel kept in the breather connected with the conservator absorbs the moisture from air when passing through breather. The Bucholz relay is connected in some transformers in between the conservator and the transformer tank for safety of the transformer. There are "oil level indicator" and thermometer installed on the transformer for the same purpose.

The transformer is used for transforming low voltage to high voltage & vice versa in a.c. supply system.

Rating of Transformer : The capacity of a transformer is expressed as KVA or MVA. 1MVA = 1000

KVA. For single phase transformer, $KVA = \frac{VI}{1000}$, for three phase transformer, $KVA = \frac{\sqrt{3}VI}{1000}$

Transformer oil : Generally mineral oil is used in the transformer. The Die electric strength of the oil should be of 40KV for 1 minute. There should not exists more than 1% sludge in the oil and the flash point of it shall not be less than 160°C. The Fire point of transformer oil should not be less than 200°C. The specific gravity will be 0.85 and there should not be any acid in the oil. The fresh oil has sale clear yellow colour. A dark colour or cloudy appearance indicate deterioration.

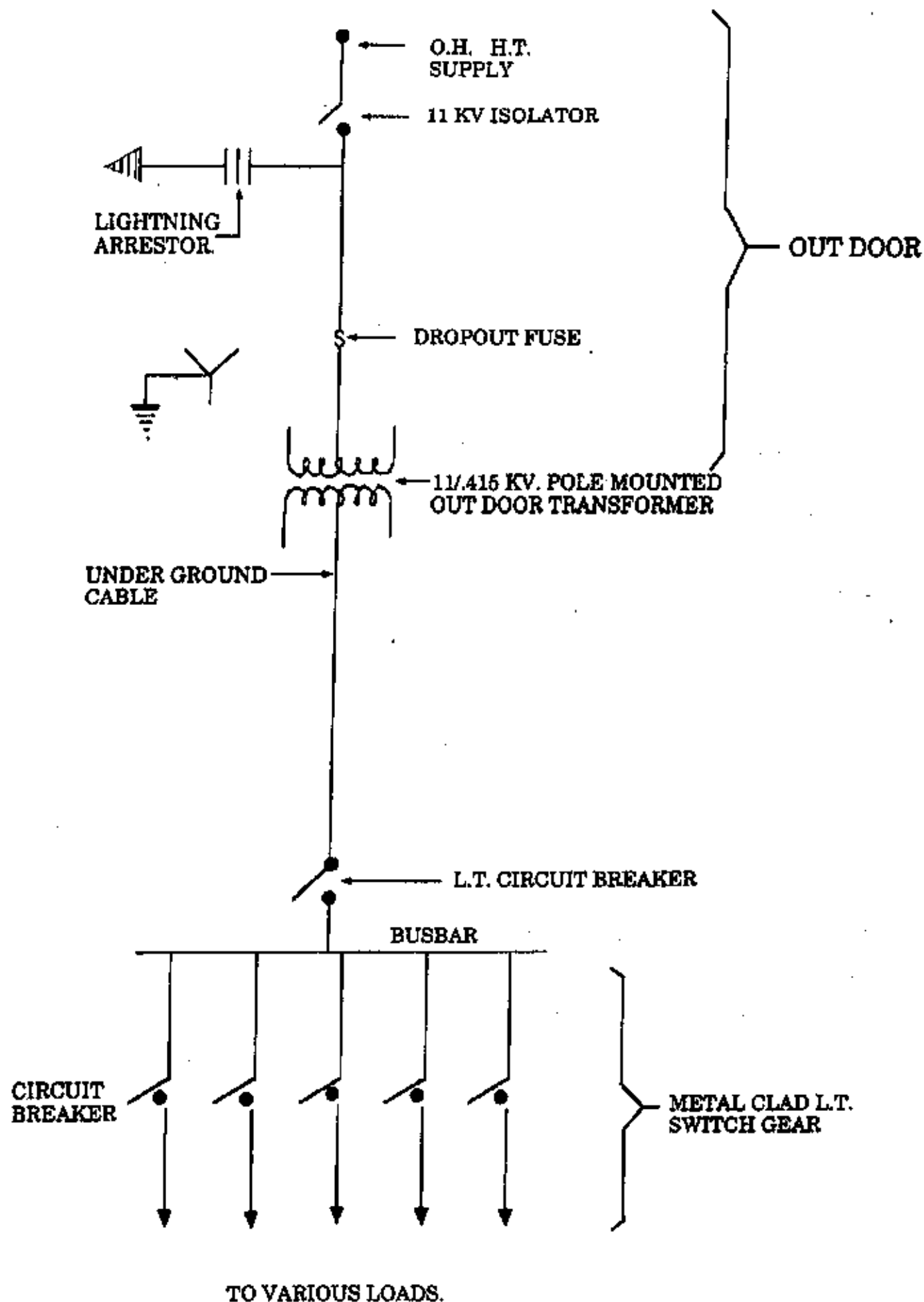


FIG. 1 TYPICAL ARRANGMENT OF POLE MOUNTED SUB-STATION

The gap between two electrodes of the oil Tester is 4 mm (0.15")

Where two or more transformers are to be installed in a sub-station to supply a medium voltage distribution system, the distribution system shall be divided into separate sections each of which shall normally be fed from one transformer only unless the medium voltage switch-gear has the requisite short circuit capacity. Provision may, however, be made to interconnect separate sections through bus couplers to cater for the failure or disconnection of one transformer.

The transformers, that at any time operate in parallel, shall be so selected as to share the load in proportion to their respective ratings.

Permissible over temperatures : Oil-filled transformers : Insulation class A; winding 65K; Oil (above) 60K.

Dry transformers :

Insulation	Class	A	E	B	F	H
winding	K	60	75	80	100	135

Marking of terminal : If the terminal marking of a transformer is not there, in the following way it can be determined : Looking at the transformer and standing in the high voltage side of it, the Red phase will be at left side, the yellow will be at the middle and at the extreme right will be the Blue phase. The corresponding Red-Yellow-Blue phase terminal on opposite will be at the low voltage side of the transformer. The neutral terminal will be at the extreme left side in the low voltage side of the transformer.

Tests of Transformer : The neutral connection should be disconnected when the insulation resistance of winding of a transformer is measured. The insulation resistance between primary and secondary winding, between windings and earth should be measured and recorded. If the insulation resistance is below the desired value the transformer should be dried and the voltage bearing capacity of the windings should be tested. One 10MVA, 33/11KV Transformer should with stand the following Test : Test voltage in primary side (33KV+10KV=)43KV up to 1 minute, in secondary side (11+10)= 21 KV upto 1 minute, all the equipment should be capable of bearing this voltage. After disconnecting all loads the test volt is applied. If the transformer sound is normal it is O.K.

The transformer oil should be changed after test if required. The dielectric strength of the oil should be 40KV for 1 minute. The insulation resistance tests of windings are done by 1000 volt megger. Insulation resistance of each bus bar to be tested after connecting the other two bus bars with earth.

Table - 1

Area Required for Transformer Room and Sub-station for Different capacities

Capacity of Transformer (KVA)	Transformer Room Area (m ²)	Total Sub-station Area (with H.T. L.T. panels & transformer room but without Generator (m ²))
1 x 150	12	42
1 x 250	13	45
2 x 250	26	90
1 x 400	13	45
2 x 400	26	90
3 x 400	39	135
2 x 630	26	90
3 x 630	39	135
2 x 1000	26	90
3 x 1000	39	135

3.5.2 High voltage switch gears : Switch gear is an essential part of a power system and also that of any electric circuit. Switch gear includes switches, fuses, circuit breakers, isolators, relays, control panels, lightning arrestors, C.T, P.T and various associated equipment.

Control gear : is a general term covering switching devices and their combination with associated control, measuring and protective equipment intended for control of power consuming devices.

Selection : should consider the followings :

- Voltage of the supply system
- the prospective short Ckt. current at the point of supply
- the size and layout of electrical installation
- the accommodation available

Guide lines on installation : Banks of switch gears shall be segregated from each other by means of fire-resistant barriers in order to prevent the risk of damage by fire or explosion arising from switch failure. Where a bus section switch is installed, it shall also be segregated from adjoining banks in the same way.

In the case of duplicate or ring main supply, switches with inter locking arrangement shall be provided to prevent simultaneous switching of different supply sources.

A circuit breaker is a switching and current interrupting device in a switch gear, which serves two basic purpose

- a) Switching during normal operating conditions for the purpose of operation and maintenance.
- b) Switching during abnormal conditions such as short Ckts. and interrupting the fault currents.

The type of switch gear; according to the arc extinguishing/quenching media used in the breaker the various types are :

- i) **ACB** (Air break/blast ckt. breaker)
- ii) **OCB** - (Bulk oil Ckt. breaker)
- iii) **MOCB** - (Minimum oil Ckt. breaker)
- iv) **VCB** - (Vacuum Ckt. breaker)
- v) **SF₆ breaker** - (Sulphur hexa fluoride gas used in the breaker cylinder)

Technical particulars of circuit breaker : A circuit breaker is identified by the following particulars :

- 1) Type of medium of Arc-extinction (Air, oil, gas SF₆ etc.)
- 2) Rated voltage. Highest power frequency voltage between phase to phase e.g. 3.6KV, 7.2KV, 12KV, 36KV, 72.5KV, 145KV
- 3) **Rated breaking current :**
- 4) **Other rated characteristics** (rated insulation level, rated frequency, rated normal current, rated short circuit breaking current, rated short circuit making current, rated operated sequence (duty cycle).)
- 5) **Type of construction :** Indoor metal clad type; outdoor type, Metal clad SF₆ gas insulated type.
- 6) Type of operating mechanism.
- 7) Total break time, e.g. 2 cycle, 3 cycle, 5 cycle.
- 8) **Structural form :** Live tank type, dead tank type.

Fault clearing time : The time elapsed between the instant of the occurrence of a fault and the instant of final arc extinction in the circuit breaker. The fault clearing time is usually expressed in cycles. One cycle of 50 Hz system is equal to 1/50 second. The fault clearing time is the sum of the relay time and the circuit breaker time.

Fault clearing time = Relay time + Circuit breaker time

Relay time = Instant of fault to closure of Trip circuit.

Circuit breaker time = Closure of Trip circuit to final arc extinction.

= Opening time + Arc extinction.

Circuit-breakers of time more than 5 cycles can now be considered as slow.

Rated characteristics of circuit Breakers : The following rated characteristics are generally specified for all high voltage a.c. circuit breakers (rated above 1000V.):

- a) **Rated voltage** - The rated voltage of a circuit breaker corresponds to the higher system voltage for which the circuit breaker is intended. The standard values of rated voltages are given in Table. The rated voltage is expressed in kVrms, and refers to line to line voltage.

Table - 2
Rated voltage of Circuit - Breaker

Nominal system voltage kVrms	Rated voltage of c.b. kVrms
0.24	.264
0.415	.474
3.3	3.6
6.6	7.2
11	12
22	24
33	36
66	72.5
132	145
220	245
400	420
500	525
750	765

- b) **Rated Insulation level**-refers to the power frequency with stand voltage and impulse voltage withstand values which characterise the insulation of the circuit breaker. The following insulations are provided in the circuit breaker :
- Insulation between live parts and earth for each pole, external and internal.
 - Insulation between poles.
 - Insulation between terminals of the same pole external & internal.
- c) **Rated Normal current** - is the rms value of the current which the circuit breaker can carry continuously and with temperature rise of the various parts within specified limits. Preferred values or rated currents. A rms area 400, 630, 800, 1250, 1600, 2000, 2500, 3150, 4000 Arms.
- d) **Rated frequency** : The standard frequency for a three pole circuit breaker is the frequency of the power system(50Hz)
- e) **Rated short circuit Breaking current** - is the highest value of short circuit current which a circuit breaker is capable of breaking under specified conditions of transient recovery voltage and power frequency recovery voltage. The breaking current refers to value of current at the instant of the contact separation. The transient recovery voltage refers to the transient voltage appearing across the circuit breaker pole immediately after the arc interruption.
- f) **Rated short circuit making current** - It may so happen that a circuit breaker may close on an existing fault. In such cases the current increase to the maximum value at the peak of first current loop. The circuit breaker should be able to close without hesitation as contact touch. The circuit breaker should be able to withstand the high mechanical forces during such a closure. The rated short circuit making current of a circuit breaker is the peak value of first current loop of short circuit current which the circuit breaker is capable of making at its rated voltage. The rated short circuit making current should be at least 2.5 times the rms. Value of a.c. component of rated breaking current.

Rated making current = $2.5 \times$ Rated short circuit breaking current.

- g) **Rated duration of short circuit :** or Rated short time current is the rms value of current that the circuit breaker can carry in a fully closed position during a specified time under prescribed conditions of use and behaviour. It is normally expressed in terms of KA for a period of one second. The rated duration of short circuit is generally one second and the circuit breaker should be able to carry short circuit current equal to its rated breaking current for one second.
- h) **Rated operating sequence : (Duty cycle)** The operating sequence denotes the sequence of opening and closing operations which the circuit breaker can perform under specified conditions. As per I.E.C. the circuit breaker should be able to perform the operating sequence as per one of the following two alternatives :-

A. o - t - co - T - co

Where, o = opening operation

c = closing operation

CO = closing followed by opening

t = 3 minutes for circuit breaker not to be used for rapid auto-reclosure

t = 0.3 second for circuit breaker to be used for rapid auto-reclosure.

T = 3 minutes.

B. co - t' - co

Where, t' = 15 seconds for circuit breaker not to be used for rapid auto-reclosure.

3.5.3 Low voltage circuit breaker: The rated characteristics of low voltage circuit breaker are slightly different from those for high voltage circuit breakers. The ckt breakers intended for ckts. below rated voltage 1000Volt a.c. or 1200Volt d.c. are low voltage ckt. breakers.

Rated voltages : Rated operational voltage-is a value of voltage of which the making and breaking capacities and short circuit performance categories refer.

Rated insulation voltage of a circuit breaker refers to the voltage to which the test voltages, clearances and creepage distances refer. Rated insulation voltage is generally the maximum operational voltage. For polyphase circuits, the rated voltage refers to voltage between phases.

Rated currents : Rated thermal current (I_{th}) is the maximum current r.m.s. value of a.c. current or steady value d.c. current, which the circuit breaker can carry in eight-hour duty.

Rated uninterrupted current : (I_u) is the value of which the circuit breaker can carry in an uninterrupted duty.

Rated duty : Eight hour duty - Uninterrupted duty.

Rated short circuit making capacity of a.c.circuit breaker at rated voltage, rated frequency and rated p.f. is the value of prospective peak current that the c.b. is capable of making and is expressed as prospective peak current. In a.c. circuit breakers the rated making capacity should not be less than the rated making capacity multiplied by factor n. The factor n is of the order of 1.41 to 2.2. (Ref table) and depends upon the rated short circuit breaking capacity.

Rated short circuit breaking capacity (I_{cn}) : in a pole of c.b. refers to the current at the initiation of arc during the breaking operation. It refers to the r.m.s. value of a.c. component of current which the a.c. circuit breaker can break under the specified conditions of voltage and p.f.

Rated short-time withstand current : refers to r.m.s. value of current (for a.c. circuit breakers) which the circuit breaker can carry for a specified short time (generally 1 second).

Type of releases : It is a device, mechanically connected to a ckt breaker, which release the holding means and permits opening or closing of ckt. breakers.

- **over load release** : over current release intended for protection against over loads.
- **Thermal over load release** responds to overloads by means of thermal action of the current flowing in the release.
- **Shunt release** : A release Energized by the voltage source, i.e. parallel to the load.
- **Under voltage release** : which permits opening of a circuit breaker when the voltage across the terminals of the release falls below a predetermined value.

Type and Routine Test of low voltage circuit breakers at manufacturers end :

Type Tests :

- verification of Temperature rise limits
- dielectric tests
- short circuit making & breaking tests
- rated short time withstand current.
- mechanical endurance test
- electrical enddurance tersts
- verification of over load performance

Routine Tests :

- mechanical operation test
- calibration of release.
- dielectric dusts

Relation between rated short-circuit making capacity, short-circuit breaking capacity and power factor of low voltage circuit breaker is given below in Table -3

Table - 3

Rate short-circuit breaking capacity (I _{cn})	Standard p.f	Minimum S.C. making capacity
I _{cn} (amp)	-	n x I _{cn}
I _{cn} ≤ 500	0.95	1.41 X I _{cn}
1,500 to 300	0.9	1.42 X I _{cn}
3,000 to 4,500	0.8	1.47 x I _{cn}
4,500 to 6,000	0.7	1.53 x I _{cn}
6,000 to 10,000	0.5	1.7 X I _{cn}
10,000 to 12,000	0.3	2.0 X I _{cn}
20,000 to 50,000	0.25	2.1 x I _{cn}
20,000 to 50,000	0.2	2.2. x I _{cn}

3.5.4 Test on High Voltage A.C. Circuit Breakers (at manufacturers end) Classified as below :

- Development Tests
- Type Tests
- Routine Tests
- Reliability Tests
- Commissioning Tests

Development Tests : (Design Tests) : These are carried out on components, Sub-assemblies, individual items, materials, poles, and complete assemblies of a circuit breaker during and after the development of the circuit breaker. It is necessary to verify the effect of various parameters on the behaviour of circuit breakers. For example, to ascertain the effect of contact speed on breakers. For example, to ascertain the effect of contact speed on breaking capacity, the circuit breaker is tested repeatedly with change in contact speed.

Type Tests : These are conducted on first few proto type circuit breakers of each type to prove the capabilities and to confirm the rated characteristics of the circuit breaker of that design. Type tests are not conducted on every circuit breaker. Type tests are performed as per recommendations of standards (IEC) or (IS).

Summary of Type Tests on H.V. A.C. Circuit Breakers.

Test	Remarks
1. No load mechanical operation tests	No load operations to verify speed of travel, opening time, closing time. Carried out at 85% and 110% rated voltage of shunt trip release.
2. Mechanical performance tests (Endurance Tests)	1000 close-open operations.
3. Temperature rise Test	Steady temperature of conducting parts and insulating parts measured for rated continuous alternating current.
4. Dielectric Tests-1.2/50 micro second. lightning impulse withstand — 1 min Power frequency voltage withstand.	Five consecutive shots of positive and then negative polarity
5. Short-time current test	Rated short-circuit current passed through closed breaker for 1 sec or 3 sec.

6.	Short-circuit breaking and making. Basic Short circuit Tests.	At 10%, 30%, 60% and 100% rated short circuit breaking current with specified operating, sequence, and specified TRV.
7.	Line charging current breaking tests.	Applicable for circuit breakers rated 72.5 KV and above to be used for overhead lines.
8.	Cable charging current breaking tests.	Applicable to circuit breaker intended for long cable net work.
9.	Single Capacitor-Bank Breaking tests.	Applicable for circuit breakers to be used for capacitor switching.
10.	Small inductive current breaking tests.	Applicable for circuit breaker with shunt reactors, transformers, reactors, motors.
11.	Out-of-phase switching	Applicable to circuit breaker which may connect two parts under out of phase conditions.
12.	Short-line Fault tests.	Applicable to circuit breakers rated above 52 KV and for overhead lines. These are in addition to basic short circuit test duties.

Routine Tests : Routine Tests are conducted on each circuit breaker before despatch. A routine test is defined as a test of every circuit breaker made to the same specifications. The routine test include the following tests :

- Mechanical operation tests
- Millivolt drop test, Measurement of resistance
- Power frequency voltage tests at manufacturers premises
- Voltage tests on auxiliary circuits

Routine tests reveal the defects in the materials and construction of circuit breaker. The results of routine tests confirm quality of circuit breaker. Five opening and five closing operations should be carried out at a) minimum supply voltage and pressure, b) maximum supply voltage and pressure.

Reliability Tests : Type tests and routine tests specified in the standards are conducted on new circuit breakers in clean and healthy condition. However, the circuit breaker installed at site is subjected to various stresses such as

- alternate variation of ambient temperatures
- extremely low temperatures
- extremely high temperatures
- rain, moisture
- vibrations due to earthquakes
- dust, chemical fumes etc.
- frequent switching in some cases
- overloads, overvoltages etc.

Commissioning Tests : After the installation, the circuit breakers and protective gear are subjected to commissioning tests, are conducted on site to ensure proper assembly and operational readiness of the equipment. These tests include :

- mechanical operation tests.
- measurement of travel, simultaneous touching of contacts.
- measurement of insulation resistance, resistance between terminals of the pole.
- precommissioning checks.
- operation open and close.
- checking of operation by energising the manual operating signal.
- checking the operation by energising of relays etc.

Insulation Resistance Measurement at site : The two terminals of megger are connected across the insulation, i.e. one to the conductor and other to earthed body. The insulation resistance indicated by the megger in megohms. For h.v. switch gear, 1000V (d.c.) megger is preferred. The insulation resistance of h.v. circuit-breaker is very high (above 1000 megohms). Insulation resistance of control circuit, trip circuit, relay circuit, secondary circuit, etc. is measured by means of 500V megger. Value obtained should not be less than 1(one) megohm.

High voltage test at site : High voltage tests are conducted after the erection of the circuit breaker. By such tests, the defective insulation or small clearance if any are brought to notice. For conducting h.v. tests, the circuit breaker is isolated suitably. The test voltage is applied between "tested part" and earthed part" as follows :

(i) with breaker closed :

a) tested part : R phase
earthed part : Y phase, B phase, frame.

b) similarly for the phase Y, B.

(ii) with breaker open :

Test across circuit breaker contacts. Join R,Y,B phases on bus-bar side. Apply voltage other inside. Consecutively to each phase.

Moreover, the circuit breaker may not be maintained by skilled personnel at times. The reliability of circuit breakers is verified by conducting special reliability tests by the manufacturer. For example, the circuit breaker is subjected to extremely low temperatures created in climatic test chambers. After the tests, the sealing rings and other parts are critically examined.

3.5.5 Interlocks : should be provided between circuit breaker, isolator and earthing switches to ensure the following sequence :

While opening :

- First to open : Circuit breaker
- Next to open : Isolator
- Then the earthing switch (if any) to close

While closing :

- Open earthing switch
- Close isolator
- Then close circuit breaker

Switches with interlocking arrangement shall be provided to prevent simultaneous switching of two different supply sources.

3.5.6 Auto reclosure : Automatic closing of the circuit breaker after its opening. It is provided to restore the service community after interrupting a transient fault. High voltage circuit breakers used for controlling overhead transmission lines are provided with such a feature.

3.5.7 Conductor - is a device capable of making, carrying and breaking electric current under normal and overload conditions.

3.5.8 HRC Fuse - High rupturing capacity cartridge fuse is used for overcurrent protection of low voltage and high voltage circuit. A cartridge fuse link has breaking capacity higher than a certain specified value (e.g. above 16KA for medium voltage).

3.5.9 The C.T. (Current transformer) ratio should be selected properly and as per load consumed in the high voltage side, e.g. 300A/5A, 100A/5A, 50A/5A. The volt ampere is relatively low. It is used for transforming the current to a lower value for the purpose of measurement, protection and control.

The C.T. Secondary should not remain open from the line. If the secondary of the C.T. is kept open dangerous high voltage may create in between the terminals. If the current coil of Ammeter,

wattmeter, Relay etc. is to be disconnected, then the secondary terminal should be short circuited first. It is better to connect one secondary terminal of the C.T. with earth for safety purposes. For this reason the secondary windings of the C.T.'s are generally made star connected and the star point is earthed. There are one or two turns in the primary winding and several turns in the secondary winding of a C.T. The primary winding is connected in series with the line. Some times the busbar/cable of the line is used as the primary of the C.T. The normal current in the secondary winding of the C.T. is kept at 5 amp. The C.T. is used for connecting Ammeter, wattmeter, power factor meter, KVA meter, Energy meter, and Relays.

Minimum Insulation resistance of transformer are given in the table below :

Table - 4

Voltage KV	Insulation resistance at different temperatures (Megohm.)					
	30°C	40°C	50°C	60°C	70°C	80°C
220	5000	2800	1200	650	380	250
132	3000	1500	700	400	200	150
66	1500	700	350	200	100	70
33	700	350	180	90	55	35
11	180	80	40	20	12	7
6.6	100	50	25	12	7	4

3.5.10 The P.T. (Potential Transformer): The volt-ampere capacity of a potential transformer is low (e.g.100 VA) and the voltage ratio is relatively high (e.g.132 KV/110V). The voltage ratio and V.A. capacity should also be looked into when selecting a switch gear. It is used for transforming the voltage to a lower value for the purpose of measurement, protection and control.

3.5.11 Relay : is an automatic device which closes its contacts when the actuating quantity/quantities reach a certain predetermined magnitude/phase. During the abnormal condition, the protective relaying senses the condition and close the trip circuit of the circuit breaker. Thereby the circuit breaker opens and the faulty part of the system is disconnected from the remaining system.

The protective relays are connected in the secondary Ckts. of C.T. and P.T.

3.5.12 Trip circuit : Figure below illustrates the basic connections of the circuit breaker control for the opening operation.

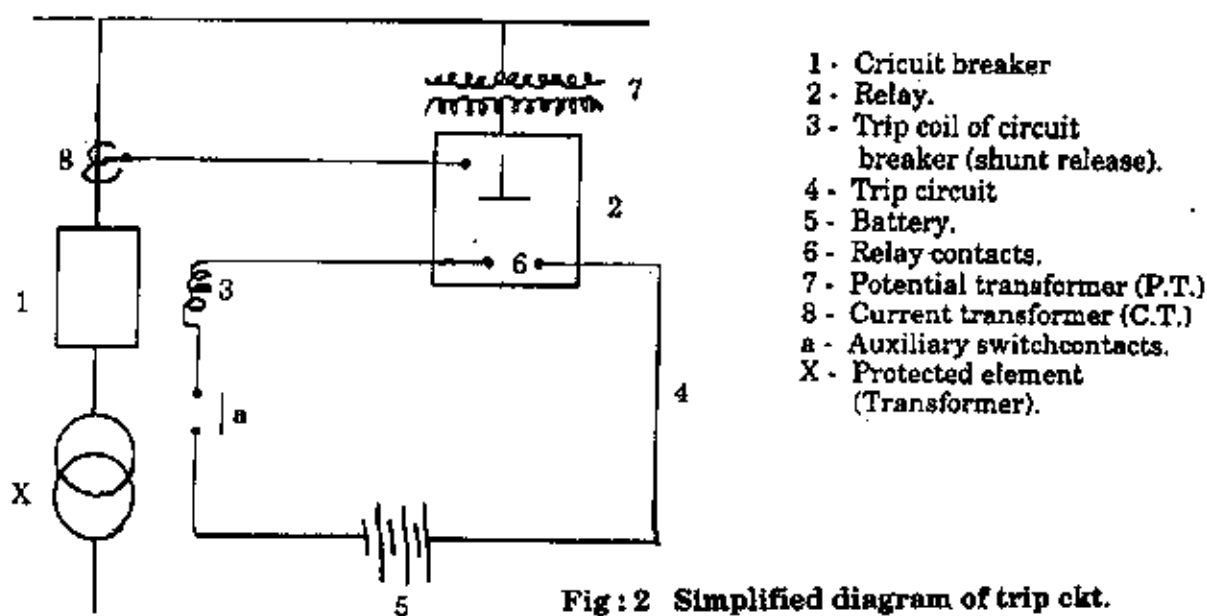


Fig : 2 Simplified diagram of trip ckt.

3.5.13 Isolator : are disconnecting switches which can be used for disconnecting/reclosing a Ckt. under no current condition. It provides isolation of a Ckt. for the purpose of maintenance. They do not have any specified current breaking or making capacity. They are generally installed in addition to the Ckt. breaker. An isolator can be opened after the Ckt. breaker is opened and closed before the ckt. breaker is closed.

3.5.14 Earthing switch : is a switch which connects a conductor to the earth so as to discharge the trapped charges on the conductor to the earth. Earthing switches are generally installed on the frames of the isolators. After opening the isolator, the earthing switch can be closed to discharge the trapped electrical charges to the ground.

3.5.15 Auxiliary switches : have standard number of pair of contacts (6,8,12). It has two positions 'open' and 'close' corresponding to the position of the circuit breaker. In each position, some auxiliary circuits are opened and some are closed. The auxiliary circuits serve several purposes.

3.5.16 Lightning Arrester (Surge diverters) - divert the over charges to earth and protect the substation equipment from over voltages.

3.5.17 Load Break Switch : In addition to isolators and circuit-breakers, there is one more device called load interrupting switch, which combines functions of the isolators and a switch. These are used for breaking load current. Load break switches are capable of making/breaking currents under normal conditions. They can carry the specified current of specified values for specified time. They are capable of making but not breaking, short circuit currents. Load break switches serve the following requirements :

- breaking rated currents
- making rated currents
- making specified S.C. currents
- carrying specified short-circuit currents
- interrupt small inductive, capacitive currents

Circuit-breakers or HRC fuses should be provided at strategic locations so as to interrupt fault currents, since load break switches cannot do so.

3.5.18 Drop out fuse : A fuse link in which the fuse carrier drops out after the operation of the fuse thereby providing isolation between the terminals.

3.5.19 Permissible duration of overload in transformer :

The permissible over load and their duration depends upon the type of cooling and insulation class of transformer. Permissible duration of overload :

Overload %	125	150	175	200	300
Duration (Minutes)	125	45	15	10	1

TABLE - 5

Present Trends in Choice of Circuit-Breakers

Rated Voltage	Prepared type	Remarks
Below 1KV (low voltage)	- Air-break Circuit-breaker	- Metal-enclosed switchgear - Metal-enclosed control gear
3.6KV to 12KV	- Minimum-Oil Circuit Breaker for majority of applications - Vacuum Circuit-breakers for special applications - SF6 C.B. recently introduced	- Metal enclosed Switchgear, Indoor Use, - Vacuum Switchgear popular in western countries. - MOCB popular in India

36KV	- Minimum oil Circuit-Breaker	Outdoor Type or in kiosk
145KV and 245KV	- Minimum oil Circuit-Breaker - SF6 Outdoor Puffer type - Air Blast Circuit-Breaker	- SF6 Circuit-breaker recently introduced, likely to be preferred
420 KV	- SF6 Outdoor Puffer type - Air Blast Circuit-Breaker	- Air Blast Circuit-Breaker - SF6 Circuit-Breaker gaining popularity and likely to supersede.

TABLE - 6
Comparison of Circuit-breakers

Type	Medium	Voltage, Breaking Capacity	Design Features	Remarks
1. Air-break circuit breaker.	Air at atmospheric pressure	430-600V, 5-15-35 MVA recently 3.6-12KV, 500MVA	Incorporates: Arc runners arc splitters, magnetic coils.	Used for medium low voltages A.C., D.C. Industrial circuit-breakers. Have current limiting features.
Miniature C.B.	Air at atmospheric	430-600V	Small size, current limiting feature.	Used for low and Medium Voltages.
2. Tank type oil circuit breaker	Dielectric oil	12KV, 3.6KV.	One tank upto 36KV, 3 tanks above 36 KV, fitted with arc control devices.	Getting obsolete, used upto 12KV, 500MVA.
3. Minimum-oil circuit breaker	Dielectric oil	Preferred for 3.6KV to 245KV.	The circuit breaking chamber is separate from supporting chamber. Small size, Arc control device used.	Used for metal enclosed switchgear upto 36KV. Outdoor type between 36 and 245KV.
4. Air-blast circuit breaker.	Compressed air (20-30 Kg/cm ²)	245KV, 35,000MVA, upto 1100KV, 50,000MVA also 36KV, 500 MVA.	Unit type construction several units per pole, auxiliary compressed air system required	Suitable for all EHV applications, fast opening closing. Also for arc Furnace Duty.
5. SF6 circuit-breaker Single pressure puffer type	SF6 gas (5 kg/cm ²)	145KV, 7500MVA 245KV, 10,000MVA 12KV, 1000MVA 36KV, 2000MVA.	Live tank/dead tank design, single pressure type preferred.	Suitable for SF6 switchgear, and Medium voltage swgs. EHV circuit breaker Maintenance free.
6. Vacuum circuit-breaker	Vacuum	Preferred for indoor switchgear rated upto 36KV, 750MVA	Variety of designs long life, modest maintenance.	Suitable for a variety of applications from 3.6KV to 36KV.
7. H.V.D.C. Circuit-breaker	Vacuum or SF6	± 500KV DC 15KA/20KA	Artificial current zero by switching in capacitors	Recently developed, likely to be used in HVDC systems.

3.6 **Insulation Test :** All transformers, switchgears etc. shall be subject to an insulation resistance measurement test to ground after installation but before any wiring is connected. Insulation tests shall be made between open contacts of circuit breakers, switches etc. and between each phase and earth.

The insulation resistance of high voltage circuit breaker is very high (above 1000 Megohm)

The insulation resistance of control circuit, trip circuit, relay circuit, secondary circuit etc. is measured by means of 500V. meggar. Value obtained should not be less than 1 Megaohm.

Insulation resistance tests shall be made between open contacts of circuit breakers, switches etc. and between each phase and earth.

3.7 MAINTENANCE OF CIRCUIT BREAKERS

Period of Inspection (For oil circuit-breakers) :

a) **Under Normal Conditions :**

1) Once in 6 months or 12 months for c.b. operating infrequently.

- 2) Once in 1 month or 3 months for c.b. operating repeatedly or according to the manufacturer's recommendations.
- b) On clearing a fault: As soon as the circuit breaker can be isolated from the service.
- c) Overhaul : Once in three years or as recommended by the manufacturer.
- d) Replacement : When the life period expires. This is a matter of economics and technical considerations.

During the periodic check-up the following checks should be made :

- a) Check the level and condition of oil. Replace the oil if necessary.
- b) Clean the insulators with fine fabric cloth that will not leave fibres. Do not use cotton waste in any case. For removing oil, grease, carbon deposit use Trichloroethylene or other chemical recommended by the manufacturer.
- c) Check contacts.
- d) Check operating mechanism.
- e) Check indicating devices.
- f) Check auxiliary switches.
- g) Tighten nuts, bolts etc.
- h) Test insulation resistance by means of high voltage (1000 Volt megger in case of high voltage circuits and by 500V. maggar on 220V. control circuits.
- i) Carry out tests according to the specifications.

When the breaker operates on fault, the internal and external inspection should be carried out as soon as the operating schedule permits :

- a) Examine the oil. If badly deteriorated, change it.
- b) Check Arcing Contacts. Clean with smooth file. If badly damaged, replace them.
- c) Inspect the insulation, carefully check the surface.
- d) Check the arc control device. If damaged, replace the plates.
- e) Check the tripping circuit and operating mechanism.
- f) Be sure that no tools are left in the tank.

Some further details are given below :

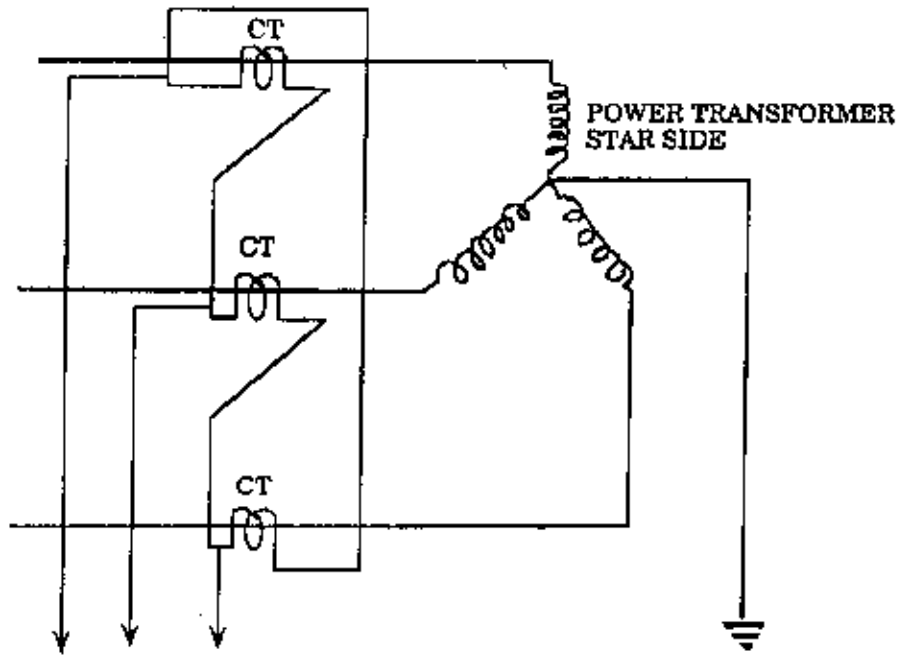
- i) The contact resistance is of the order of 20 micro-ohms for 1200A. normal current rating, the resistance between the ends of pole gives the measure of the contact resistance.
- ii) If contacts are badly burned they should be replaced.
- iii) If lightly burned or pitted or metal globules are present or the surface is slightly uneven, they are cleaned by fine glass paper or fine file. On any account the contacts of the circuit breaker should not be oiled or greased.

Arc Control Devices : Slight blackening is not harmful. The condition of plates is important. If badly burned or deformed the entire arc control device may need replacement. All vents and openings should be cleaned.

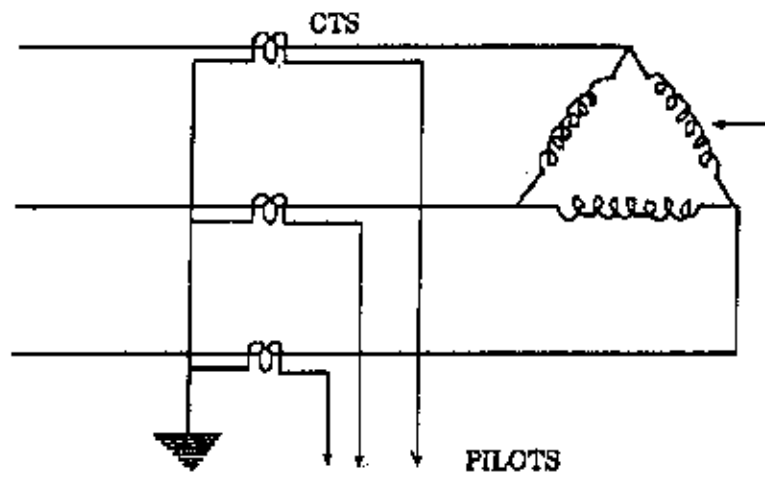
Insulators : Porcelain insulators should be inspected for any sign of cracks or defects. They should be cleaned with trichloroethylene. Carry out tests recommended by the specifications.

Operating Mechanisms : Check opening and closing operation by manual signal and tripping by means of relay. Clean all moving parts. Lubricate the sliding parts and surfaces. Avoid excessive Lubrication. Check the tightness of nuts-bolts pins, etc. Check the springs. Check the terminal blocks and the wiring. Check the auxiliary switch.

Relays : It is advisable not to adjust the relay-mechanism. The faulty relay should be sent to the manufacturer since relay repair is a specialized job.



Connection of CT secondaries on star side.



Connections of CT secondaries on deltaside.

Contacts of relays should be inspected for any sign of burning where necessary, glass paper should be used for cleaning. All the terminals of the relay should be checked for tightness. The wiring should be checked for security.

Safety : The following steps to be taken for carrying the maintenance work :

- a) Isolation of the part from live parts during the period of maintenance. No switching on by mistake.
- 2) Danger notices such as the one given below should be placed.
- 3) The neighbouring points should be locked to avoid switching by a third person.
- 4) Earthing. The work, equipment and conductors should be earthed by means of earthing connections, from both ends.
- 5) Power tools, safety devices should be provided to the electricians.
- 6) The electricians should be well trained.
- 7) First-aid should be available.
- 8) Switching on should be allowed only after completion of work.

" Death can be caused even on 400V installations, because of negligence."

3.8 ROUTINE MAINTENANCE TESTS OF RELAYS

Deterioration of protective relays : Dampness causes weakness of insulations, polluted atmosphere affects the relay contacts, relay parts. Dust affects insulations, relaying system. Relay room should, therefore be made dust proof and vermin proof.

3.8.1 Relay maintenance : Relay rooms should be made dust-proof.

- Inspection for any sign of burring, brushing of contacts. (use glass paper)
- Foreign matter removal.
- Adjustments checking.
- Breakers Tripped by manual contact closing.
- Screws checks for tightness.
- Covers cleaning.
- Maintenance Tests.

3.8.2 Relay Maintenance Test : by primary current Injection Test sets :

Most protective gear is fed from a current transformer on the supply cable or bus bars and PRIMARY current injection testing checks aparts of the protection system by injecting the test current through the primary circuit.

The primary injection tests can be carried out by means of primary injection test sets. These sets are standard portable sets comprising ;

- Current supply unit.
- Control unit.
- Accessories.

The test set can give variable output current. The output current can be varied by means of built-auto-transformers. The primary injection test set is connected to a.c. single phase supply. The output terminals can be connected to in the primary circuit of C.T. The primary current can be varied by means of the injection set.

Relay Maintenance Test by secondary current Injection test sets :

Secondary current injection checks the operation of the protective gear but does not check the overall system including the current transformer. However, it is rare for a fault to occur in the current transformer and the secondary test is sufficient for most routine maintenance.

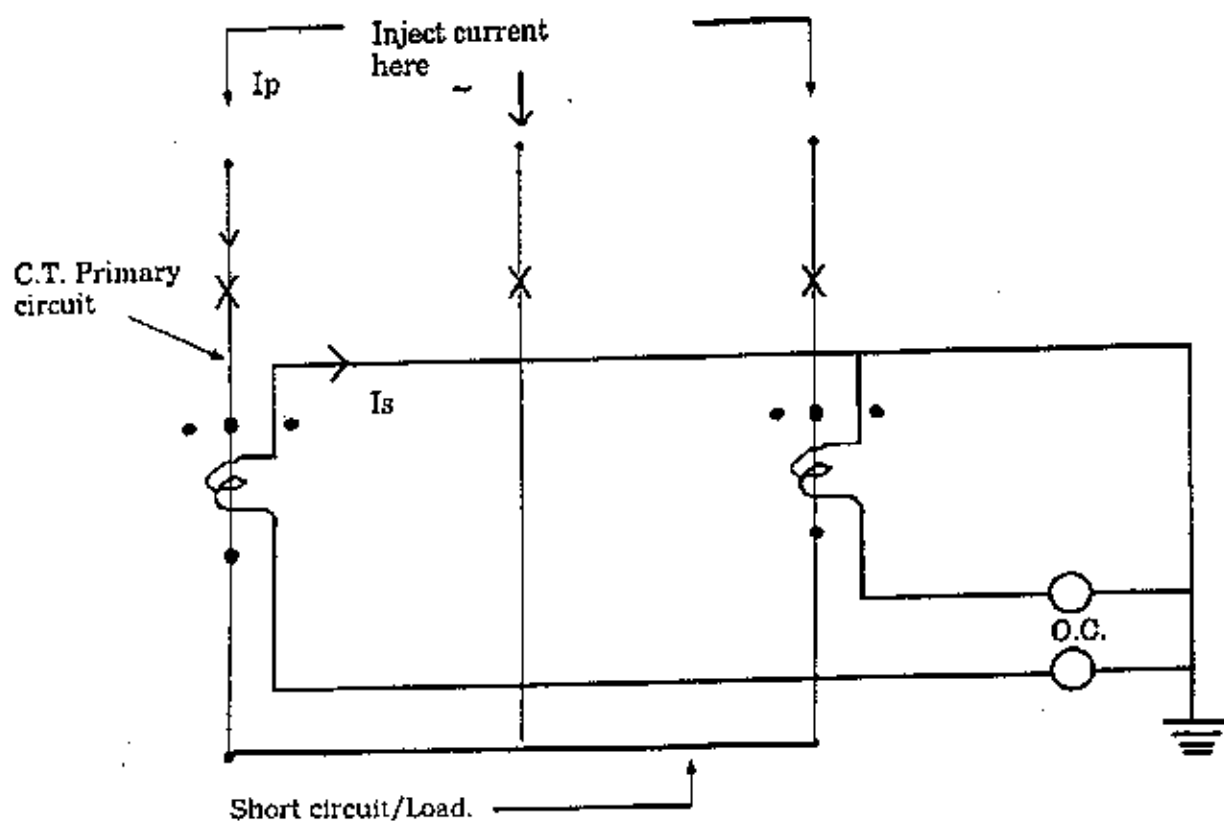


Fig - 3 : Primary Injection

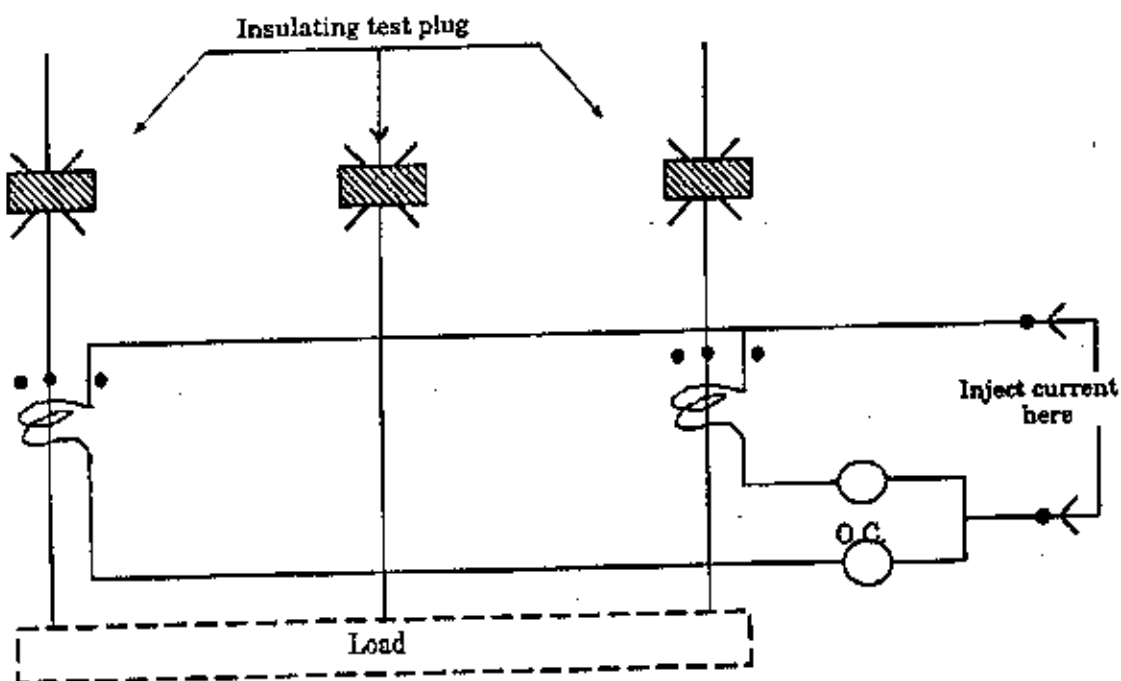


Fig - 4 : Secondary injection

The primary test is essential when commissioning and new installation as it tests the whole protection system and will detect current transformers connected with incorrect polarity or relays that have been set in wrong sequence in differential systems.

Secondary current injection sets are very useful for conducting these tests.

The Standard Secondary Current Injection Testing Equipment consists of a 50A. current injection set, separate waveform filter unit and a digital counter. The equipment is designed as a portable kit for onsite testing of protective devices, circuit-breakers, trip coils motor overloads and similar apparatus.

3.9 CONTINUOUS OBSERVATION

- Pilot supervision.
- Trip circuit supervision.
- Relay voltage supervision.
- Battery earth fault supervision.
- Bus-bar protection C.T. circuit supervision.
- Relay Flags.
- Battery voltage.

A trained person should be on duty to observe the above mentioned aspects. Secondary injection tests, Buchholz relay tests should be done once in a year. Periodic relay Testing should be done. Manually close (or open) contacts and observe that they perform their required functions i.e. trip, reclose, block etc. gradually apply current or voltage to see that pickup is within limits. Reduce the current until the relay drops out or fully resets. This test will indicate excess friction.

The protective relays remain stand still and without operation until a fault develops. However the relay should be vigilant at all times. For reliable service of protective relaying excellent maintenance is a must. Lack of proper maintenance may lead to failure to operate. Every relay has a provision of setting. Setting determines pick-up value/time setting of various relays need co-ordination.

3.10 NECESSARY CHECKS

In substation installation, it shall be checked whether :

- The installation has been carried out in accordance with the approved drawings;
- Phase to phase and phase to earth clearances are provided as required.
- All equipment are efficiently earthed and properly connected to the required number of earth electrodes;
- The required ground clearance to live-terminals is provided;
- Suitable fencing is provided with gate with lockable arrangements;
- The required number of caution boards, fire-fighting equipment, operating rods, rubber mats, etc. are kept in the substation;
- In case of indoor substation sufficient ventilation and draining arrangements are made;
- All cable trenches are provided with non-inflammable covers;
- Free accessibility is provided for all equipment for normal operation;
- All name plates are fixed and the equipment are fully painted;
- All construction materials and temporary connections are removed;
- Oil-level, busbar tightness, transformer tap position, etc. are in order;
- Earth pipe troughs and cover slabs are provided for earth electrodes/earth pits and the neutral and LA earth pits are marked for easy identification;
- Earth electrodes are of G.I pipes. For earth connections, brass bolts and nuts with lead washers are provided in the pipes.
- Earth pipe troughs and oil sumps/pits are free from rubbish and dirt and stone jelly and the earth connections are visible and easily accessible;

- HT AND LT panels and switchgears are all vermin and damp-proof and all unused openings or holes are blocked properly.
- The earth bus bars have tight connections and corrosion-free joint surfaces;
- Control switch-fuses are provided at an accessible height from ground;
- Adequate headroom is available in the transformer room for easy topping-up of oil, maintenance, etc.
- Safety devices, horizontal and vertical barriers, busbar cover/shrouds, automatic safety shutters/door interlock, handle interlock etc are safe and in reliable operation in all panels and cubicles;
- Clearances in the front, rear and sides of the main HV and LV and sub-switch boards are adequate;
- The switches operate freely, the blades make contact at the same time, the arcing hours contact in advance; and the handles are provided with locking arrangements.
- Insulators are free from cracks, and clean;
- In transformers, there is no oil leak;
- Connections to bushing in transformers are tight and maintain good contact;
- Bushings are free from cracks and are clean;
- Accessories of transformers like breathers, vent pipe, buchholz relay, etc. are in order.
- Connections to gas relay in transformers are in order;
- In transformers, oil and winding temperature are set for specific requirements to pump out;
- In case of cable cellars, adequate arrangements exist to pump out water that has entered due to seepage or other reasons
- All incoming and outgoing circuits of HT and LT panel are clearly labeled for identifications.

Medium Voltage Installation : In medium voltage installations, it shall be checked whether :

- All blocking materials that are used for safe transportation in switchgears, contactors, relays, etc. are removed;
- All connections to the earthing system are feasible for periodical inspection;
- Sharp cable bends are avoided and cables are taken in smooth manner in the trenches or alongside the walls and ceiling using suitable support clamps at regular intervals;
- Suitable linked switch or circuit breaker or lockable push button is provided near the motors/apparatus for controlling supply to the motor/apparatus in an easily accessible location;
- Two separate and distinct earth connections are provided for the motor apparatus;
- Control switch fuse is provided at an accessible height from ground for controlling supply to hoists, overhead busbar trunking;
- If flexible materials hose is used for wiring to motors and other equipment, the wiring is enclosed to the full lengths and the hose secured properly by approved means;
- The cables are not taken through areas where they are likely to be damaged or chemically affected;
- The screens and armours of the cables are earthed properly;
- The belts of belt driven equipment are properly guarded;
- Adequate precautions are taken to ensure that no live parts are so exposed as to cause danger;
- Ammeters and voltmeters tested, and
- The relays are inspected visually by moving covers for deposits of dusts or other foreign matter.

**LOCATION OF SWITCH GEAR IN POWER SYSTEM
(SINGLE LINE SIMPLIFIED DIAGRAM)**

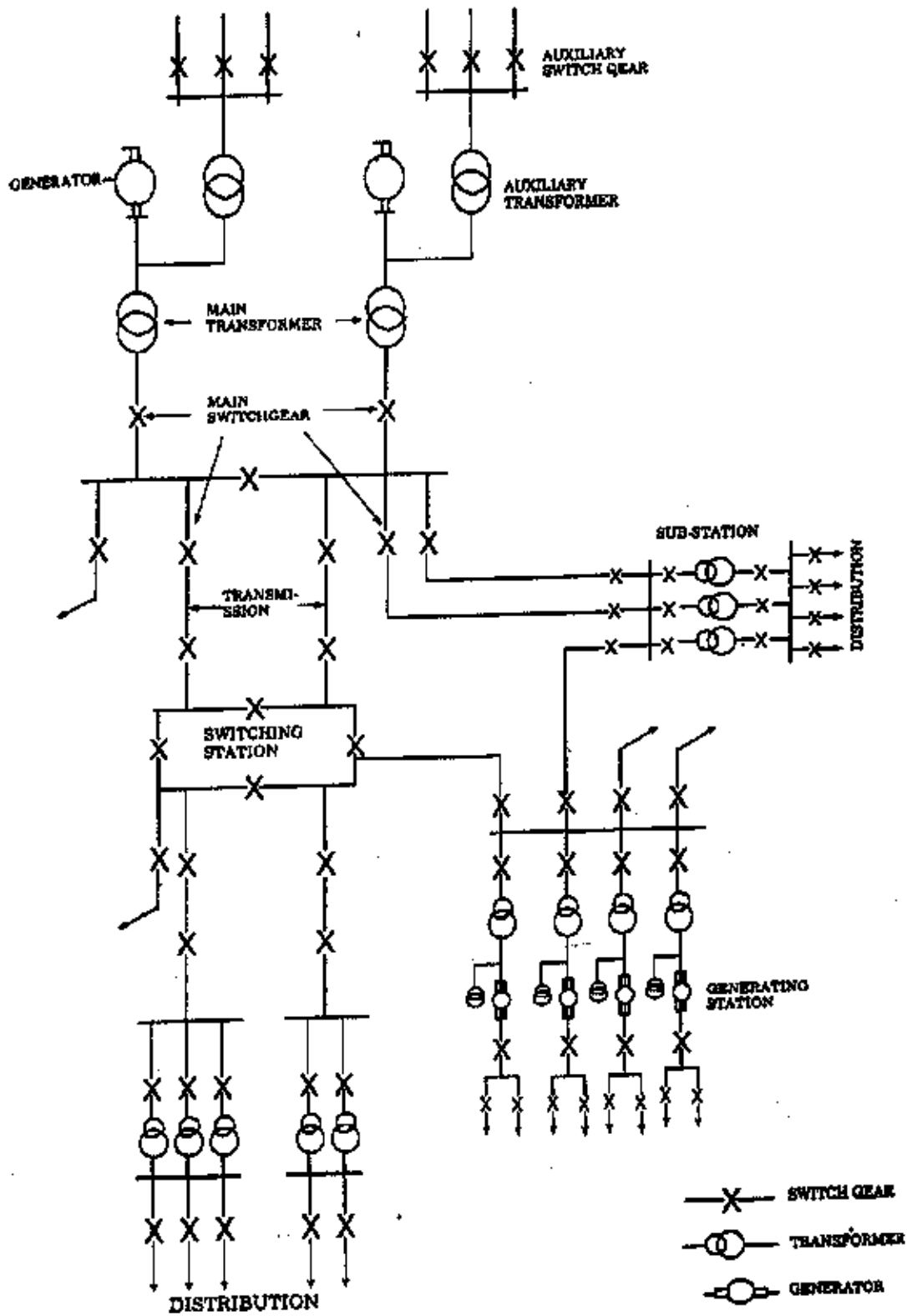


Fig : 5

TABLE - 7

Power Transformer Protections

Abnormal condition	Protection	Remarks
Insipient faults below oil level resulting in decomposition of oil faults between phase and between phase and ground.	Buchholz relay sounds alarm (Gas actuated relay) Sudden pressure relay Pressure relief valve	Buchholz relay used for transformors of rating 500KVA and above
Large internal faults phase-to-phase, phase to ground, below oil level	(1) Buchholz relay trips the circuit-breaker	Buchholz relay too slow and less sensitive. Buchholz relay for tapchanger also.
Faults in tap-changer	(2) Percentage differential protection (3) High speed high set overcurrent relay.	Percentage differential protection used for transformors of and above 5MVA.
Saturation of magnetic circuit	(1) Over fluxing protection (2) Overvoltage protection	For important generator transformer and feeder transformors.
Earth faults	(1) Differential protection (2) Earth fault relay	For transformors of and above 5MVA. (a) Instantaneous Restricted E.F. Relay (b) Time lag E.F. Relay
Through faults	(1) Graded time lag overcurrent relay (2) HRC Fuses	Protection of distribution transformors. Small distribution transformors upto 500KVA
Overloads	(1) Thermal overload relay (2) Temperature relays sound alarm.	Generally temperature indicators are provided on the transformors. Temp increase is indicated on control board also. Fans started at certain temp.
High voltage surges due to lightning, switching.	(1) Horn gaps (2) Lightning arresters	Not favoured for important transformors. In addition to L.A.'s for incoming lines.
Small distribution transformors	Only H.V. fuses for earth faults protection and phase fault protection. Overload protection generally not provided. For more important transformors of about 500KVA. Overcurrent relays Instantaneous earth fault relays.	
Transformer in important locations, ratings 500KVA above		Restricted earth-fault protection Overcurrent protection Buchholz relay.
Transformer of about 5 MVA and above		Differential protection, Restricted earthfault protection, Overcurrent protection, Overfluxing protection, Buchholz Relays, Sudden pressure relays.

Colours of Push buttons (to VDE, IEC & DIN)

<u>Meaning of colour</u>		<u>Typical applications</u>
Red	Stop, Off	To stop machines, deenergize magnetic clamping devices, stop cycle.
	Emergency Off	Emergency stop, disconnection in case of dangerous heating.
Green/Black	Start, On	To-energize control Circuits(supply available), initiate starting of motors for auxiliary function, energize magnetic clamping devices.
Yellow	Start of return movement outside the normal working cycle or Start of a movement to suppress dangerous conditions.	Return of machine elements to the starting point of a cycle before it has been completed, Actuating the Yellow push button can cancel other preselected functions.
White or light blue	Any specific functions not covered by the above colours.	Resetting of protective relays, control of auxiliary functions which are not connected with the working cycle.

Colours of Indicator lights.

Red	Abnormal conditions	Indication that the machine has been stopped by action of a protective device - because of overload, travel or other fault. Indication for the operator to stop the machine, e.g. because of overload.
Yellow (amber)	Caution	Available (current, temperature) approaches its limit value, signal for the automatic cycle.
Green	Machine ready to start	Machine ready to start, all auxiliary devices are in working order etc.
White (colour less)	Circuit energized, Normal operation	Main switch in "On" position, selection of speed or direction of rotation, individual drives & auxiliaries are in operation, machine is running.
Blue	All functions which are not covered by the above colours.	

Illuminating push buttons

	Meaning	Function	Application
Red (Indication)	Red shall, wherever possible not be used	Stop (not emergency off)	
Yellow (Amber) indication	Caution	Start of an action to suppress abnormal conditions	Available approaches its limit value. The actuation of this button can cancel the functions previously selected.
Green (indication)	Machine may be started as push button lights up.	Start of machine or unit.	For normal operation start of motors, machines, energizing of magnetic circuits or clamping plates.
Blue Indication	Any specific meaning not covered by above.		
White (clear) confirmation.	Continuous confirmation that a circuit is energized or that a function or movement has been started or preselected.	Closing of a Circuit or starting operation or preselection	Any preselection or any starting operation

**CAPACITOR RATINGS FOR LOAD FACTOR
IMPROVEMENT**

Existing load factor cos	Capacitor loading in kvar per kW active load, for power factor cos				
	0.80	0.85	0.90	0.95	1
0.40	1.54	1.67	1.81	1.96	2.29
0.42	1.41	1.54	1.66	1.83	2.16
0.44	1.29	1.42	1.56	1.71	2.04
0.46	1.18	1.31	1.45	1.60	1.93
0.48	1.08	1.21	1.34	1.50	1.83
0.50	0.98	1.11	1.25	1.40	1.73
0.52	0.89	1.02	1.16	1.31	1.64
0.54	0.81	0.90	1.08	1.23	1.56
0.56	0.73	0.86	1.00	1.15	1.48
0.58	0.66	0.78	0.92	1.08	1.41
0.60	0.58	0.71	0.85	1.00	1.33
0.62	0.52	0.65	0.78	0.94	1.27
0.64	0.45	0.58	0.72	0.87	1.20
0.66	0.39	0.52	0.66	0.81	1.14
0.68	0.33	0.45	0.59	0.75	1.08
0.70	0.27	0.40	0.54	0.69	1.02
0.72	0.21	0.44	0.48	0.64	0.96
0.74	0.16	0.29	0.43	0.58	0.91
0.76	0.11	0.24	0.37	0.53	0.86
0.78	0.05	0.18	0.32	0.47	0.80
0.80	-	0.13	0.27	0.42	0.75
0.82	-	0.08	0.21	0.37	0.70
0.84	-	0.03	0.16	0.32	0.65
0.86	-	-	0.11	0.26	0.59
0.88	-	-	0.06	0.21	0.54
0.90	-	-	-	0.10	0.43
0.92	-	-	-	0.04	0.36

Example:

Existing power factor cos - - - = 0.76

Desired power factor cos - - - = 0.90

Capacitor rating as per table - - -
= 0.37 kvar/kW

Active load (For example meter reading) - - - = 140kW

Required capacitance = $0.37 \times 140 = 51.8$ kvar selected: 50 kvar.

LOCATING ELECTRICAL FAULTS AND REMEDYING OF LOW VOLTAGE INDUCTION MOTORS

Type of fault	Possible causes	Remedy operates.	Protective device that
1 Motor fails to start up	2 Supply phases open circuited	3 Inspect control gear (contactors, fuse)	4 Thermal protection (Thermistor type detectors)
Thermal overload protection operates on starting	Open circuit in direct on or star delta starter Brushes made no contact with sliprings Rotor or fan rubbing on stator	Inspect contacts and terminal connections Provide for correct brush movement in holders; replace worn brushes. Locate mechanical trouble; check air gap.	Thermal protection or circuit breaker with bimetal relay.
Motor starts up sluggishly; excessive speed reduction when motor is loaded.	Worn contacts of star delta starter. Excessive load torque on starting. Terminal voltage too low. Supply voltage too low, (Voltage dip when motor is loaded). One motor terminal was by mistake connected to neutral instead of phase lead.	Repair starter or condor. Reduce load torque; use rotor for higher torque class. Measure voltage; use supply cable of larger size; reduce load. Measure voltage; use other transformer tap, if necessary. Install cable of larger cross section. Correct connection, correct supply connections. Inspect short circuit; repair rotor winding.	Thermal protection.
Motor hums a) During start up b) When running.	Unequal phase resistance; open circuit or interturn short circuit on rotor. Short circuit between turns or parts of stator winding; multiple winding-to-frame short-circuit (earth fault).	Repair winding or replace it; measure phase currents which may be unequal.	Thermal Protection or bimetal relay.
Thermal overload protection operates while motor is running.	System frequency too high; excessive core losses. Single phasing. Open in stator winding or supply cable, stator winding incorrectly connected; star instead of delta. Motor was incorrectly selected for type of duty involved, e.g. for short time or intermittent duty instead of continuous duty at full load. Air flow obstructed. Thermal overload protection incorrectly rated or adjusted.	System frequency should not exceed 105% rated value. Provide for correct three-phase connection. Compare with rating plate data and correct. Check whether correct type of motor has been selected. Use larger motor. Measure rate of cooling air. Correct fan adjustment, direction Remove dirt deposits from air path, adjust air guides. Check and correct setting of overload protection.	Thermal Protection. Circuit breaker with bimetal relay.

STAND BY SUPPLY**4.1 SHORT DESCRIPTION**

The Generating set Comprises of the Following Salient Features

- Engine
- Alternator
- Control panel

4.1.1 The Engines are fitted with
Lubricating oil, air and fuel filters.
Fuel lift pump.
Fuel control solenoid.
Engine Temperature switch.
Oil pressure switch.
Starter motor.
Charge alternator.
Radiators and Engine driven cooling fan.

4.1.2 Alternator consists essentially of two important parts : (1) an even set of electromagnets or permanent magnet and (2) The laminated steel core containing current carrying copper wires, the latter being called the armature winding. A-C Generators, generally called alternators, are nearly always constructed so that the armature core and its winding are stationary while the field poles rotate. The alternator is coupled to the Engine flywheel.

4.1.3 Control panel : It is fitted with the following :

- Ammeters with matching C.T.
- Volt meter with selector switch.
- Frequency meter.
- Hours counter.
- KW meter.
- Set of instrumentation and battery supply fuses.
- Suitably rated out put circuit breaker with thermal and magnetic over load protection.
- Mains failure engine protection unit.
- Auto closing breaker etc.

4.2 CAPACITY

The capacity of the stand by Generating set shall be chosen on the basis of essential light load, essential Air condition load and essential service load. The Generator should be housed in the Sub-station building to enable transfer of electrical load quickly as well as to avoid transfer of vibration and noise to the main and attached building. The Generator room should have proper ventilation and fire fighting equipment installed.

4.3 INSTALLATION/COMMISSIONING

4.3.1 Unpack it, ensure it for conformity to the packing list and for transit damage. If damaged, advise the carriers and the sender immediately.

4.3.2 Installation

Electrical work should only be carried out by qualified electrical personnel.

- For air cooled sets, arrange the layout so that the inlet air is ducted from the power house inlet louvres. Duct the outlet air to outside atmosphere so that there is little risk of drawing heated air back into the inlet.
- For water cooled sets, set the radiator close to the outlet louvres. Alternatively use canvas ducting and place the set so that the radiator is between 300mm and 1000mm from the louvres.
- In all cases, site the set with a minimum of 1m clear maintenance access space on both side and at the alternator end.
- Mount on a level concrete floor of sufficient strength to carry the weight of the set.
- The generator frame should be solidly bonded to the generating set bedplate. If antivibration mounts are fitted between the generator frame and its bedplate a suitably rated earth conductor should bridge across the antivibration mount.
- Test the insulation resistance of windings. AVR should be disconnected during this test. A 500 Volt Megger should be used. Disconnect any earthing conductor connected between neutral and earth and megger an out put lead terminal U.V or W to to earth. The insulation resistance should be in excess of 5 Megohm to earth.
- Fit the exhaust run, which should be reasonably short and should include a flexible pipe below immediately at the engine exhaust outlet. Fit the silencer and tail pipe of at least 0.5m in length. Protect the tail pipe against the ingress of rainwater. Note that exhaust systems and silencers reach very high temperatures during operation, so lapping with 50mm thick mineral wool wire mat (96 kg/m³ density) is recommended.
- Ensure adequate air ventilation.
- If air cooled engine, duct the exit air flow to the outside so that it does not mix with the inlet air flow.
- Set the fuel tank for convenience of access for filling.
- Install good lighting (for maintenance use).

4.3.3 Preparation For Running

- Remove the temporary covering protecting the radiator (if applicable) and air vents for transit.
- Remove all masking tapes from the engine pipework, including and masking the crank case breather and the fuel rack system.
- The generator is supplied to give a phase sequence of UVW with the generator running clockwise to looking at the drive end.
- Remove any transit securements.
- Open up the control panel and terminal box covers and check that all parts and connections are secured. Particularly check the heavy current connections.
- Check the fuel solenoid for free movement, secure electrical connections and absence of obstruction to governor linkages.
- Check the battery charge alternator on the engine for tight connections.
- Check over the belts on the engine for correct tension and absence of damage.
- Ensure alignment of drive and driven pulleys to avoid axial load on the bearings.
- Fill and charge the battery (see battery leaflet).

Table - 1

Area Requirement for stand by Generator Rooms

Capacity (K.W)	Area (m ²)
1 x 25	20
1 x 48	24
1 x 100	30
1 x 150	36
1 x 300	48
1 x 500	56

- Close the fuel and coolant drain cocks (normally left open when the plant is drained after factory test). Check that the engine sump drain plug is tight.
- If water cooled engine, fill the radiator to the correct level, add approved inhibitor and if appropriate, anti-freeze (refer to the engine handbook).
- Tighten all connections on the pipework system of the engine and radiator (if applicable).
- Incorrect belt tensioning will result in excessive bearing wear.
- Fill the engine sump to the correct level with recommended lubrication oil (see engine handbook).
- If the engine is fitted with a turbo-charger, carry out pre-run lubrication procedure (see engine manufacturer's handbook).
- Fill the fuel tank with the correct grade of fuel oil (see engine handbook), check that the fuel taps are turned on. Check the system carefully for leaks and eliminate them.
- Minimum instrumentation for testing should be line to line or line to neutral volt-meter, Hz meter, load current metering and kw meter.
- Using the recommendations in the engine handbook, bleed the air out of the engine fuel system.
- Check the air cleaners for cleanliness and security.
- Ensure all guards and covers are in place.
- Connect the starter battery terminals in correct polarity (+ve to +ve and -ve to -ve. Connect -ve or earth terminal last).
- Smear the battery terminals with petroleum jelly (vasaline) to protect against corrosion.

4.3.4 Initial Run

During the initial run, make careful observation of any sign of malfunction. Should any occur, shut down the set immediately and investigate using skilled assistance if required.

Electrical work should only be carried out by qualified electrical personnel.

- Start the set "OFF LOAD".
- The engine speed will have been factory adjusted to 1500rpm at full load. Check that the no-load speed is within 2 to 2½ Hz higher.
- Adjust the alternator voltage to the required nominal value (see alternator manual).
- Check the lubricating oil pressure indicator to ensure that a good pressure is being built up (see engine handbook for pressure value).
- After a few minutes running, check for leaks, fuel, coolant or lubricating oil.
- Switch set to load and allow the set to run 15 minutes on load, progressively increasing load where possible to full load and observe :

- Temperature indicators (where fitted). Should come up to temperature within the first few minutes and stabilise.
- Oil pressure gauge. Oil pressure should be maintained.
- Voltage. Should be maintained with + 1%.
- Frequency. Should be stable within 2HZ (50HZ sets) as load changes.
- Leaks. Should be corrected when the set is shut down. Carry out a detailed examination of the set, including :
 - Rectify leaking joints.
 - Re-check lubricating oil and replenish to correct level.
 - Re-tighten exhaust pipework joints (beware: The pipes will be hot!).
 - Re-check radiator coolant (if applicable) and replenish to correct level (CAUTION:- A hot system may be pressurised).
 - Re-tighten radiator pipe work joints (if applicable).

4.3.5 Safety

Before operating the generating plant ensure that the following conditions are satisfied :

- The operator is familiar with the operation of the set, all controls and location of manually operated valves and shutdown devices.
- Information regarding first aid procedure and facilities should be displayed near the generating plant.
- With the use of fuel and lubricating oils, there is a fire hazard and health can be at risk through handling, unless preventive action is taken. It is recommended that the user contacts their supplier of fuel/lubricating oils for the manufacturer recommendations on Health and Safety.
- Generating sets emit noise and it is recommended that personnel exposed to noise should wear adequate protection e.g. ear defenders.
- On automatic starting plant, a warning plate advising personnel that the plant may start automatically without warning must be prominently displayed.
- Appropriate fire-fighting equipment should be to hand (CO₂ or BCF type fire extinguishers recommended).
- The metalwork of the generating plant, bed frame and other exposed parts must be bonded to an effective earth point.
- The appropriate neutral earthing requirements must be complied with.
- Care must be taken to avoid spillage from battery and naked flames and sparks should not be allowed in the vicinity of the batteries, particularly when they are on charge.
- Safety guards and covers must be securely fitted and all cubicle doors, cover plates etc. should be firmly in place when the set is operational.
- The area around the generating plant should be cleared of obstructions and dangerous objects and the floor should be kept dry and clear of oil deposits.
- No loose or other items of equipment should be left on or near the generating set.
- Maintenance work, particularly in confined areas should preferably be carried out by two operators working together.
- Before any maintenance work is carried out, all supplies to the generator should be isolated, the plant battery should be disconnected and suitable warning plate stating "MAINTENANCE IN PROGRESS" should be displayed.
- Designate the vicinity of the generating plant a NO SMOKING area and one prohibited to unauthorised persons.
- Over speeding of the generator during initial setting of the speed governor can result in damage to the generator rotating components. Adjustment of the engine governor must be such that the generator will not be subjected to speed in excess of 125% of the rated speed.
- The voltage should not be increased above the rated generator voltage shown on the generator name plate.

4.4 MAINTENANCE

4.4.1 Caution :

Before carrying out any maintenance work :-

- Select Operation Mode Control switch to position OFF.
- Read "GENERATING SET SAFETY CODE"

4.4.2 Generally, a standby set should be checked weekly and run for a short period, preferably on load, to exercise both the engine/alternator and its control panel. All information and readings should be recorded. The suggested schedule check sheet may be used as a guide to establish a maintenance programme to fit any specific operation. The time between checks could vary depending upon site conditions e.g. high dust laden atmosphere, which the maintenance schedule should take into account.

4.4.3 In special cases a standby set should be checked daily and run for a short period on no load.

4.4.4 A fault that occurs quite frequently even when maintenance is carried out regularly, is the engine injectors fouling due to excessive light load running. As will be seen from the typical maintenance schedule, a figure of 50 per cent loading is mentioned. This load factor should be considered as a minimum and a full load factor would be more desirable followed by 110 per cent load for a short period.

With this load factor it does ensure that the engine does not suffer from injectors being 'clogged' with carbon deposits due to unburnt fuel. Also, running on a light load could in the time dilute the engine lubricating oil.

4.4.5 The basic maintenance schedule should cover the following services :

- Check condition of air cleaners, fuel oil filter elements and lubricating oil filter elements, change if necessary.
- Check cooling water level, leaks and anti-freeze mix if applicable.
- Check lubricating oil level and leaks and top up or change if necessary.
- Check fuel oil levels and leaks.
- Check fuel injectors.
- Check fan belt condition and tension correct if necessary.
- Check starter battery condition, voltage and specific gravity of electrolyte.
- Check alternator brushes if applicable, replace as necessary.
- Check condition of switchboard lamps, fuses, meter, contactors and other switches.
- Check output of battery charger.
- Check for loose electrical and mechanical connections, tighten as necessary.
- Check regulation of alternator voltage and frequency.
- Simulate "MAINS FAILURE" operation.

SUGGESTED MAINTENANCE SCHEDULE CHECK SHEET

	ACTION	10 HOURS or WEEKLY	100 HOURS or MONTHLY	200 HOURS or YEARLY
1. ENGINE	1.1 Check lubricating oil level 1.2 Change lubricating oil 1.3 Check fuel tank level 1.4 Check water coolant level 1.5 Check anti-freeze content in cooling system 1.6 Check vee belt tension 1.7 Clean air filter or if oil bath type check level 1.8 Check all fuel, exhaust, air piping for leaks 1.9 Drain sediment from fuel tank 1.10 Check & clean radiator matrix			
2. ENGINE ELECTRICS	2.1 Check electrolyte level in battery 2.2 Check state of charge in battery with hydrometer 2.3 Clean cable terminations on battery and regrease 2.4 Check fuel solenoid is operating correctly 2.5 Check auxiliary terminal box connections			
3. GENERATOR	3.1 Clean exteriors and internally with a dry air supply 3.2 Grease bearings (if required) 3.3 Check ventilation areas for obstructions			
4. CONTROL PANEL	4.1 Check functioning of control system 4.2 Check functioning of all switches (including engine) 4.3 Check that contacts of circuit breakers and contactors are clean 4.4 Check condition and rating of fuses and tripping device			
5. GENERAL	5.1 Check and tighten all nuts and bolts (as required) 5.2 Check condition of anti-vibration mounting (if fitted)			
6. COMPLETE SET	6.1 Run set for one hour minimum preferably on 50 per cent load Check and Note : 1. Approximate starting time 2. That all engine instruments are functioning 3. That all meters are functioning 4. All indications are operating correctly 5. All switches are functioning 6.2 Clean complete set and exterior of panel and remove dust			
7	7.1 Have generating set inspected by manufacturer			

CAUTION :

Fault finding, particularly electrical, is a form of testing and should only be carried out by qualified personnel. Attention must be given to operators safety. All normal safety precautions must be taken.

4.5 FAULT DIAGNOSIS TABLE

FAULT	POSSIBLE CAUSE	ACTION REQUIRED
Engine speed drops notably on load	<ul style="list-style-type: none"> - Obstruction to governor linkage or to free movement of fuel solenoid. - Incorrect fuel - Water in fuel line - Fuel filter blocked - Fuel supply line blockage 	<p>Remove obstruction.</p> <p>Check fuel specification (see engine manual).</p> <p>Bleed out defective fuel.</p> <p>Clean/replace filter.</p> <p>Trace blockage and clear it, check that some fuel exits from spill return pipe.</p>
Plant shuts down on overspeed	<ul style="list-style-type: none"> - Overspeed - Governor mechanism jammed 	<p>Locate and rectify cause.</p> <p>Check and rectify.</p>
Plant shuts down on overtemperature	<ul style="list-style-type: none"> - Restricted ventilation/cooling 	<p>Check cooling system.</p> <p>Check radiator (if water cooled) for accumulation of dirt.</p> <p>Check operation of cooling fan and ventilation louvres if appropriate.</p>
Engine fails to run	<ul style="list-style-type: none"> - Battery fault - Battery supply fuse ruptured - Faulty start relay (RS) - Mode selector switch in wrong position 	<p>Connect/retit battery. Charge battery and check electrolyte.</p> <p>Replace fuse.</p> <p>Check/replace relay RS</p> <p>Check for switch position.</p>
Engine turns but does not run	<ul style="list-style-type: none"> - No fuel - Faulty fuel solenoid - Engine injectors defective 	<p>Fill tank & bleed system.</p> <p>Check/replace fuel solenoid.</p> <p>Service engine (see engine manual).</p>
Set does not supply load	<ul style="list-style-type: none"> - Set output breaker not closed. - Faulty main contactor auxiliary contact - Faulty standby contactor or coil - No supply for standby contactor - No alternator excitation - interlocks on change-over contactors out of adjustment. 	<p>Close breaker.</p> <p>Check contact.</p> <p>Check contact</p> <p>Check terminals.</p> <p>Check, adjust.</p>
Plant shutdown on low oil pressure	<ul style="list-style-type: none"> - Blocked engine oil filter - Low oil level in sump 	<p>Change filter.</p> <p>Check and top up if necessary.</p>
Plant breaker trips on overload	<ul style="list-style-type: none"> - Overload - Load circuit fault - Phase loading too great on one phase. 	<p>Reduce load/adjust pattern of load switching.</p> <p>Locate and rectify fault.</p> <p>Adjust pattern of load distribution.</p>
Voltage fluctuating	<ul style="list-style-type: none"> - Frequent switching of heavy load. - Low power factor of load - Automatic voltage regulator fault. - Alternator fault 	<p>Adjust pattern of load switching</p> <p>See Alternator manual.</p> <p>See Alternator manual.</p> <p>See Alternator manual.</p>
Excessive vibration	<ul style="list-style-type: none"> - Fuel problem - Loose coupling - Faulty bearing 	<p>Refer to engine manual.</p> <p>Shutdown and rectify.</p> <p>Locate and replance.</p>

4.6 MAINTENANCE OF LEAD ACID BATTERY

4.6.1 THE DO'S

- Keep the battery and battery area clean and dry at all times.
- Ensure the vent caps are securely screwed or pushed home.
- Keep the battery terminals and connections free from corrosion and coated in petroleum jelly.
- Maintain the electrolyte to the required levels by the addition of distilled or de-ionised water only.

4.6.2 THE DON'TS

- NEVER lay tools or metal objects across the top of the battery.
- NEVER add tap or well water. Always use distilled water or de-ionised water for topping-up the electrolyte.
- NEVER allow the battery to become completely flat (fully discharged).
- NEVER allow the battery to stand in a discharged condition or damage will result.
- NEVER allow the battery electrolyte level to drop below the top of the plates.

4.6.3 Remember that a battery requires attention at all times, even when it is not working.

5.1 TYPES OF PUMPS

Pumps are generally classified as reciprocating and rotary pumps. Rotary pumps are again divided into 3 main groups. They are radial flow (also called centrifugal), mixed flow and axial flow.

Radial or centrifugal pumps, frequently with two or more stages, are used for high heads. For large discharge and small heads axial pumps and for medium head and medium discharge mixed flow pumps are used.

5.2 PUMPS SPECIFICATION

While ordering for a pump the total head H , discharge Q , speed N , pump efficiency and shaft input power are specified.

5.3 CENTRIFUGAL PUMP

5.3.1 Total Head H (m)

It is the increase of energy imparted to the liquid flowing from inlet to outlet of the pump.

For calculating the head of a centrifugal pump, in planning a pumping installation the total head is sum of (a) total head, (b) difference of pressures in the source and delivery tanks, (c) sum of all head losses in the system and (d) velocity head at exit of delivery pipe line. The head losses include the losses in foot valve, pipe line, bends, valves and measuring instruments, if any.

While determining the total head of a centrifugal pump experimentally, pressure gauges or manometers are connected near the suction and delivery flanges of the pump. The head losses include the losses in foot valve, pipe line, bends, valves and measuring instruments, if any. The total head is the sum of the differences of (a) pressures in the gauges, (b) velocity heads in suction and delivery pipes and (c) heights of the gauges.

$$5.3.2 \text{ Actual h.p.} = \frac{\text{gpm} \times 8\frac{1}{3} \times \text{d.c.}}{33000 \times E} = \frac{\text{cu.ft.} \times 62.4 \times \text{d.c.}}{33000 \times E}$$

$$\frac{\text{gpm} \times 10 \times \text{d.c.}}{33000 \times E}$$

Where d.c. = dynamic column

gpm = gallon per minute

62.4 = wt. of one cubic ft of water at room temp.

$8\frac{1}{3}$ = approximate wt. of one gallon (U.S.gall) of water in pound.

10 = approximate wt. of one gallon (Imp. gall) of water in pound.

E = efficiency of the pump, expressed as a decimal.

$$\text{Theoretical h.p.} = \frac{\text{gpm} \times 8\frac{1}{3} \times \text{d.c.}}{33000} = \frac{\text{cu.ft.} \times 62.4 \times \text{d.c.}}{33000}$$

Dynamic Column = Dynamic Head + Dynamic Lift.

$$d. c = H_D + L_D$$

L_D = Static lift (L_g) + Friction losses

from water level to intake of pump.

H_D = Static head (H_g) + Friction resistance
in discharge line including elbows

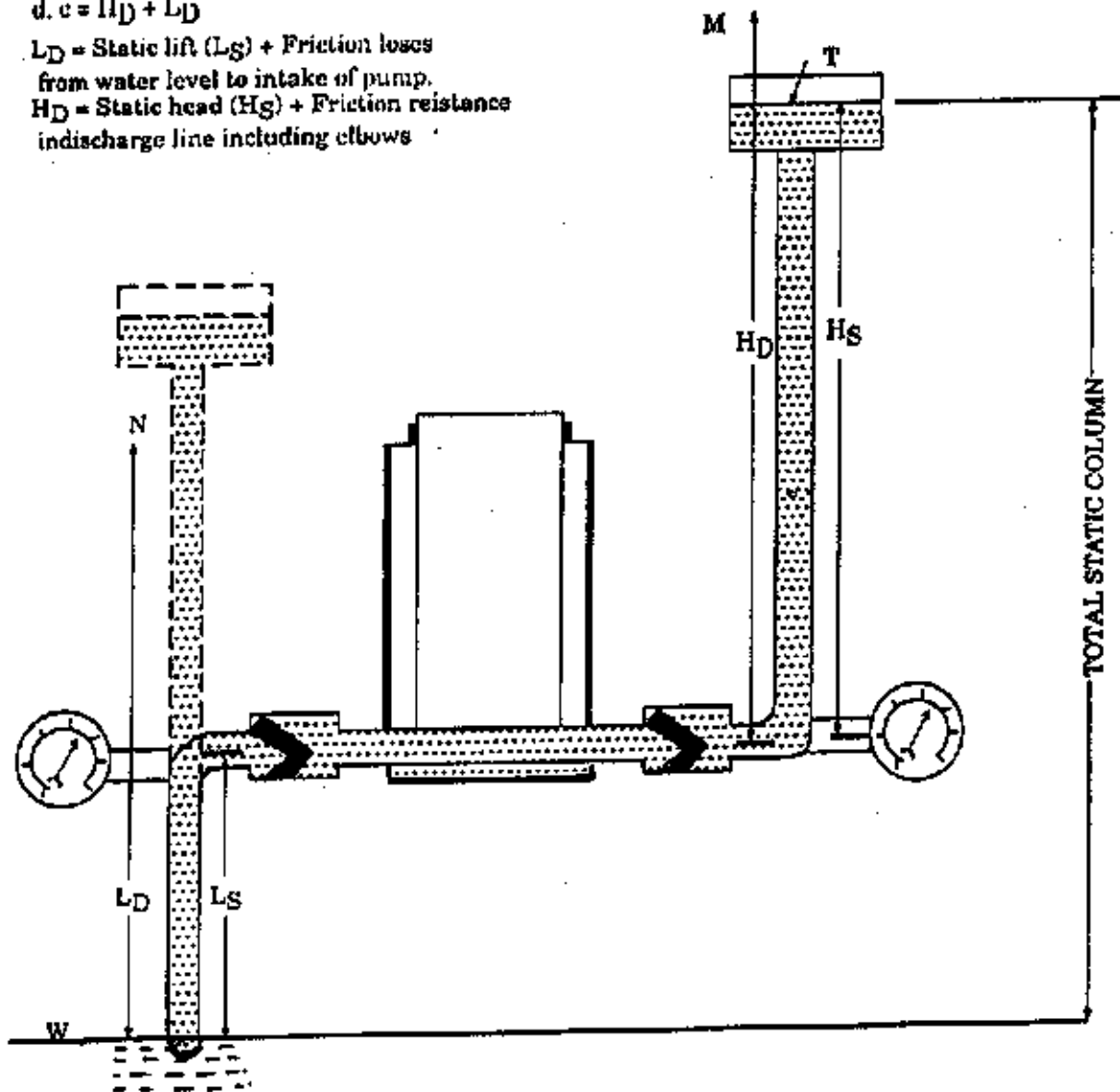


Fig-1

Fig. 1 Gauge method of obtaining static and dynamic head, static and dynamic lift, and static and dynamic total column.

5.3.3 Installation

Suction side

Reliable operation of the pump depends upon the correct installation of the suction line. The horizontal part of suction line must always rise towards the pump to avoid formation of air pockets. If reducers are used in suction line they should be eccentric. Sluice valve used should have its spindle in horizontal direction. Sluice valves in the suction line are only intended to enable the line to be isolated when necessary for inspection. Bends should be used instead of elbows.

Suction strainer with foot-valve should be installed at an adequate depth so that air can not enter. At the same time it should be sufficiently above the floor level so as to avoid mud and sand entering the suction side, each pump should be provided with its own suction line to avoid leakage of air from a pump which is not working. Flow velocity in the suction line should not exceed 2 m/s.

In case of flanged joints, gaskets must not project into the bore to choke the flow.

Delivery side :

Flow velocity in delivery side is to be limited to 3 m/s. A non-return valve is to be installed if the delivery head exceeds 10m (32 feet). The non-return valve avoids the sudden surge of large water masses in the backward direction in case of a sudden stoppage of the pump.

A sluice valve is necessary in the delivery side. Overloading a pump may be avoided by closing sluice valve.

Concrete foundation beds should be allowed to set and dry before installation of the pump. After fitting the pipe lines and the motor, the shaft must be easily movable by hand. The axis of pump and motor must be aligned. This is checked with the help of straight gauge placed on the coupling and slowly rotating the pump shaft by hand. Shimms may be placed at the bolt connections for correct alignment.

5.3.4 Operation of Pump :

While starting a pump the suction line must be filled with water. The delivery valve must be closed. After the rated speed is achieved the delivery valve is to be opened.

The passage between the pump shaft and the pump casing is lubricated by water. The packing in the stuffing box is not to be tightened too hard and there must be a constant drip of water (about 30 to 45 drops per minute) through the stuffing box. For stopping the pump the delivery valve is to be closed first in case where non return valve not used.

5.3.5 Maintenance

Oil level in the bearing pedestal must be checked before starting a pump. Oil is to be completely changed after 2000 hours of operation.

The pump should be periodically opened to check the condition of impeller. While running the impeller should not touch the casing specially at the suction cover. There must be a clearance between the impeller and the suction ring.

5.3.6 Star-delta operation

Starting : Push button S1A energises star-control K2M and time relay K4A. NO contact of K2M energises line contactor K1M, lock in contacts of K1M and K2M close. The motor runs upto speed in the star step.

Change over : At the end of set delay period NC contact of K4A opens, and star contactor K2M de-energizes. Then the NC contact of Star contactor K2M closes and delta contactor K3M will be closed because the NO contact of the line contactor K1M had already been closed after closing of the line contactor. The motor then runs in the delta step.

Stopping : By pressing push button SOA line contactor K1M opens. NO contact of K1M then opens and delta contactor K3M and motor is switched Off.

5.3.7 Abnormal Operating conditions : Centrifugal pumps should run smoothly and without vibration when they are operating properly. The bearings operate at a constant temperature which may be affected by the location of the units. This temperature may range as low as 100°F but the operating temperature is usually maximum temperature at minimum flow varying with pump capacity.

If a pump for some reason either does not contain liquid or becomes vapour bound vibration occurs due to contact between the stationary and the rotating parts and the pump may become over heated Vapor may be blown from the glands and in extreme instances the thrust bearings may suddenly increase in temperature and damage result from the rotor being forced in a single direction.

If the pump is overheated because of a vaporized condition and the rotor has not seized open all vents and prime or flood liquid into the pump. A low temperature liquid should not be admitted suddenly to a heated pump because fracture or distortion of its parts may result. An overheated pump should not be used unless an emergency exists to save a boiler from damages for example.

Vibration also may result from excessive wear on the pump rotor or in the pump bearing which cause the pump and motor shafts to become misaligned. These should be corrected at the first opportunity. If a rotor has seized it is necessary to dismantle it completely and to rectify the parts by filing, machining etc.

5.3.8 Location of Troubles and their Causes

Many difficulties may be experienced with centrifugal pumps Location of these troubles and their causes are discussed here.

Reduced Capacity or Pressure and Failure to Deliver Water. When the capacity or pressure of the pump is reduced and the pump fails to deliver water any of the following may be the cause.

- Pump is not primed
- Low speed
- Total dynamic head is higher than the pump rating
- Lift is too high (normal lift is 20 ft.)
- Foreign material is lodged in the impeller
- Opposite direction of rotation
- Excessive air in water
- Air leakage in inlet pipe or stuffing boxes
- Insufficient inlet pressure for vapor pressure of the liquid
- Mechanical defects such as worn rings damaged impeller and defective casing gasket
- Foot valve is either too small or is restricted by trash
- Foot valve or inlet pipe is too shallow

Loses water after Starting: If the pump starts and then loses water, the cause may be :

- Air leak in inlet pipe
- Lift too high (over 15ft.)
- Plugged water-seal pipe
- Excessive air or gases in water

Pump Overloads Driver : If the driver is overloaded by the pump check the following :

- Speed too high
- Total dynamic head lower than pump rating, pumping too much water
- Specific gravity and viscosity of pumped liquid different from pump rating
- Mechanical defects.

Pump Vibrates : The causes of pump vibration may be :

- Misalignment
- Foundation not rigid enough
- Foreign material causes impeller unbalance

Mechanical defects such as bent shaft, rotating element rubbing against a stationary element and worn bearings.

Centrifugal pumps can be operated only in one direction. The arrow on the casing indicates the direction of rotation. During pump operation the stuffing boxes and bearing should be inspected occasionally. The pump should be disassembled, cleaned and oiled if it is to be idle for a long period of time. If the pump is to be exposed to freezing temperatures it should be drained immediately after stopping.

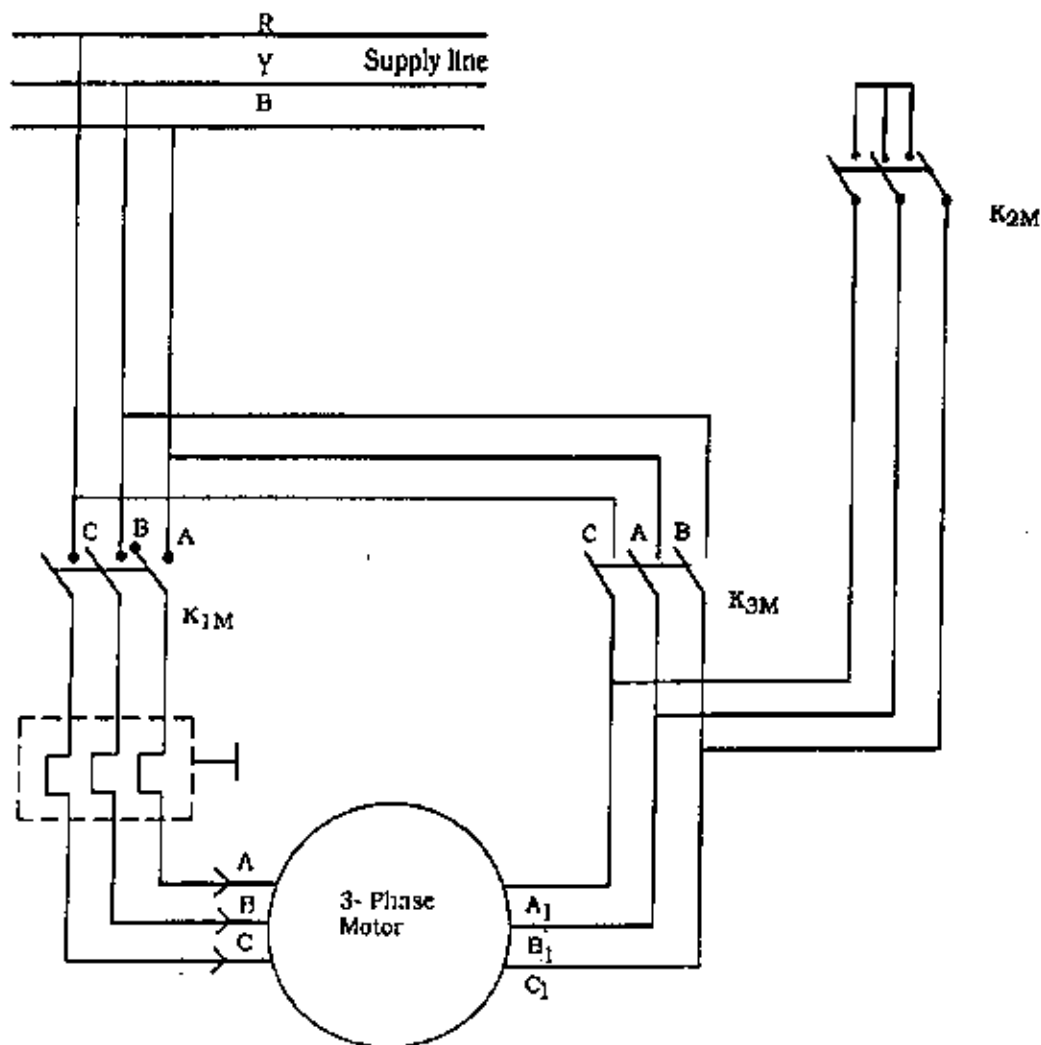


Fig - 2 star - delta starting connection of a 3-phase pump - Motor

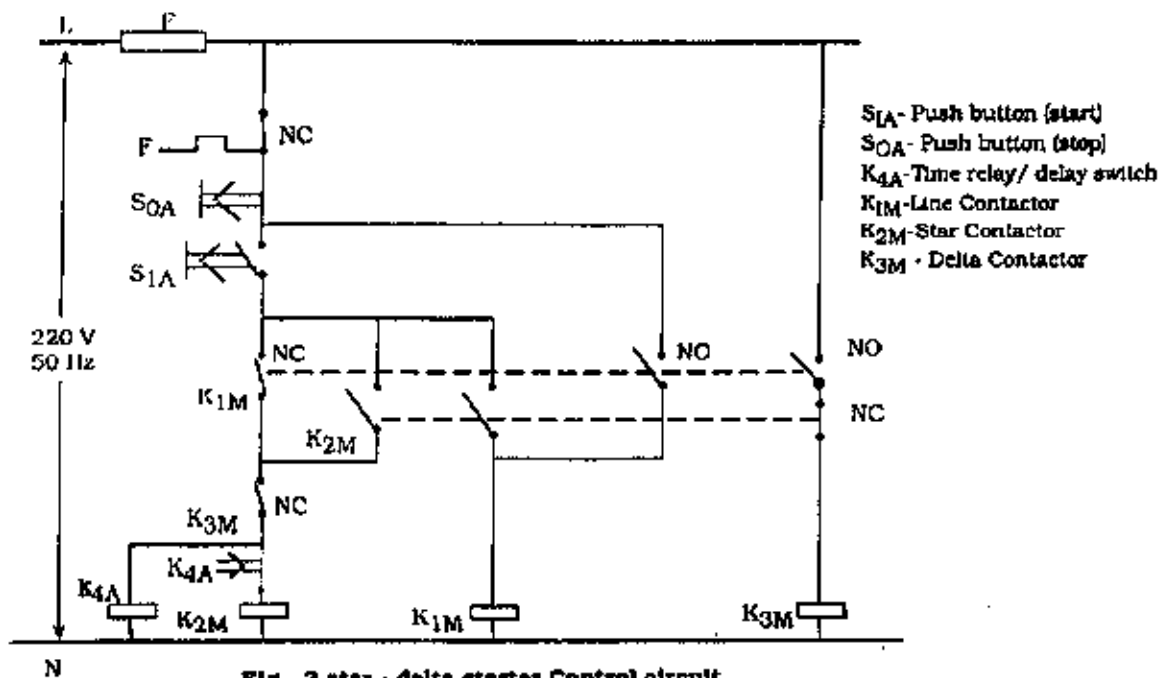


Fig - 3 star - delta starter Control circuit

Insufficient Liquid Delivered :

One of the following causes may result in delivery of insufficient liquid :

- Air leak in the inlet line or through the stuffing box. Oil and tighten the stuffing box gland. Paint the inlet pipe joints with shellac.
- Speed too slow. The rpm should be checked. The driver may be overloaded; or the cause may be due to low voltage or due to low steam pressure.
- Lift may be too high. Check with vacuum gauge. Small fractions in some liquids vaporize easily and occupy a portion of the pump displacement.
- Too much lift for hot liquids.
- Pump may be worn.
- Foot valve may not be deep enough.
- Foot valve may be either too small or obstructed.
- Piping is improperly installed, permitting air or gas to pocket inside the pump.
- Mechanical defects such as defective packing or damage pump.

Pump delivers for a short period then quits :

This may be a result of one of the following causes :

- Leak in the inlet line.
- End of the inlet valve is not deep enough.
- Air or gas in the liquid.
- Supply is exhausted.
- Vaporization of the liquid in the inlet line. Check this with the vacuum gauge to be sure that the pressure in the pump is greater than the vapor pressure of the liquid.
- Air or gas pockets in the inlet line.
- Pump is cut by presence of sand or other abrasives in the liquid.

Rapid Wear : Some of the causes of rapid wear in a pump are :

- Grit or dirt in the liquid that is being pumped. A fine-mesh strainer or filter can be installed in the inlet line.
- Pipe strain on the pump casing causes the working parts to bind. The pipe connections can be released and the alignment checked to determine whether this factor is a cause of rapid wear.
- Pump operating against excessive pressure.
- Corrosion roughens surfaces
- Pump runs dry or with insufficient liquid.

Pump Requires Too Much Power: Too much power to operate the pump may be required by :

- Speed too fast.
- Liquid either heavier or more viscous than water.
- Mechanical defects such as a bent shaft, binding of the rotating element stuffing boxes too tight and misalignment caused by improper connections to the pipe lines or installation on the foundation in such a way that the base is sprung.
- Misalignment of the coupling (direct-connected units)

Noisy Operation : The causes of noisy operation may be :

- Insufficient supply which may be due to liquid vaporizing in the pump. This may be corrected by lowering the pump and by increasing the size of the inlet pipe.
- Air leaks in the inlet pipe can cause a crackling noise in the pump.
- Air or gas pockets in the inlet.

Suggestions on pump Operation: Various abnormal conditions may occur during pump operations:

- If the pump discharges a small quantity of water during the first few revolutions and then churns and fails to discharge more water air is probably still in the pump and piping or the lift may be too great or check for a leaky pipe, a long inlet pipe and lack of sufficient head.
- If the pump produces a full stream of water at first and then fails, the cause is failure of the water supply or the water level receding below the lift limit. This can be determined by placing a vacuum gauge on the inlet elbow of the pump. This problem can be remedied by lowering the pump to reduce the lift.
- If the pump delivers a full stream of water at the surface of pump level but fails at a higher discharge point the pump speed is too low.
- If the pump delivers a full stream of water at first and the discharge decreases slowly until no water is delivered an air leak at the packing gland is the cause.
- If a full stream of water is delivered for a few hours and then fails the inlet pipe or the impeller is obstructed if the flow from the water supply is unchanged.
- If heavy vibration occurs while the pump is in operation the shaft has been sprung the pump is out of alignment or an obstruction has lodged in one side of the impeller.
- If the bearings become hot the belt is unnecessarily tight the bearings lack oil or there is end thrust.
- If hot liquids are to be pumped the lift should be as small as possible because the boiling point of the liquid is lowered under vacuum and the consequent loss of priming is due to presence of vapor.
- If the water is discharged into a sump or tank near the end of the inlet pipe there is great danger of entering air into the inlet pipe.
- If a pump is speeded up to increase capacity beyond its maximum rating a waste of power results.
- If a pump remains idle for some time its rotor should be rotated by hand once each week for long periods of time.

5.4 ROTARY PUMPS

5.4.1 Starting and Operating the Pump. Before starting the pump it should be primed, then the prime mover should be checked for proper direction of rotation. Pressure or vacuum should be checked on the inlet side and pressure should be checked on the outlet side to determine whether they conform to specifications and whether the pump can deliver full capacity without overloading the driver.

Operation should be started at a reduced load gradually increasing to maximum service conditions. Pumps with external bearings may require occasional lubrication or soft grease for the bearings. If grease fittings are not furnished on pumps with internal bearings lubrication is not necessary.

5.4.2 Location of Troubles and their Causes :

Rotary pumps like centrifugal pumps normally require little attention while they are running. However most troubles can be avoided if they are given only a small amount of care rather than no attention at all. Some of the more frequent causes of trouble are indicated here.

No Liquid Delivered :

The following causes and steps should be taken if no liquid is delivered :

- Stop pump immediately
- If pump is not primed prime according to instructions
- Lift may be too high. Check this factor with a vacuum gauge on the inlet. If the lift is too high lower the position of the pump and increase the size of the inlet pipe, check the inlet line for air leaks
- Incorrect direction of rotation

- A pump that is out of alignment may cause metallic contact between the rotors and the casing.
- Operating against excessive pressure.
- Coupling out of balance.

5.5 DEEP WELL TURBINE PUMP

Centrifugal pumps are used where suction lift is low. But in case the level of water is far below the ground level, deep well turbine pumps bowl assembly containing the impeller is submerged in water.

- 5.5.1 The pump bowl assembly is suspended from discharge head by means of an assembly of column pipes. Column pipes and column pipe couplings are placed alternately. A vertical hollow shaft motor, placed on the discharge head, drives the impellers through shaft assembly passing through the column pipe assembly. The shafts are held in bearings placed in spiders in column pipe couplings.
- 5.5.2 The total head of pump may be increased by increasing the number of stages.
- 5.5.3 In the suction side a bell mouth is attached for smooth entry of water in the pump.
- 5.5.4 The characteristic curves of DWT pumps are similar to centrifugal pumps. For a particular stage the head and discharge can be lowered by trimming the impeller. The impellers are generally mixed flow type.

5.6 Installation of Submersible Pump

5.6.1 Equipment for pump installation :

Following equipments and tools are required for installation of submersible pumping set :

- Derrick or tripod with chain pulley block and swivel load-hook of 3 tons capacity for pumping sets upto 15 HP or of 5 tons capacity for sets above 15 H.P. Height of derick or tripod should allow the load hook to be raised to 3 or 4 m and it should be erected for the hook to be directly above well axis.
- Two pairs of supporting clamps, suitable for the column pipe.
- About a metre long section of threaded and coupled column pipe.
- Threading compound (Five parts graphite and one part red lead mixed with lubricating oil or semi-dried lead base paint).
- Chain or wire rope sling.
- Two chain spanners.
- Two pipe spanners.
- 50 megohm portable megger.
- Mechanical and electrical hand tools.
- Data of the bore-well showing depth, straightness, diameter of casing pipes, static water level, draw down level and yield.

5.6.2 Checking Installation :

Before coupling the pump and motor, check the motor for insulation continuity and direction of rotation. The wooden rubber protector can be removed from the adaptor of the motor by unscrewing the cap screws provided for connecting the pump and motor. Clean the top face of the motor with kerosene so that no dirt/grease remains.

A bronze sand collar is provided on the rotor shaft; remove this for the time being. Open the two drain plugs provided on the motor adaptor and fill the motor with cold, clear and fresh water.

Filling should be done slowly, so as to allow inside air to escape. Fill water till it starts flowing out from the hole at the top side. As soon as the motor is filled with water, close the drain plugs alongwith the washers. Remove the coupling from the pump shaft and coupling key which is strapped to the pump adaptor.

Check by fitting the coupling on motor shaft (file or emery the key if necessary), it should slide easily. After coupling, and its key are in position on motor shaft turn it by hand; it should move freely. Remove coupling and key and check the pump similarly.

Insulation test : Once the motor is full of water, connect, earth lead of megger to motor adaptor on the top surface (where there is no paint) and the line lead to the red, yellow and blue leads of the connecting cable by turns. When the megger handle is cranked it should read between 20 and 50 megohms.

The splice or joint in the cable can now be checked by putting the joint under water in a container. The earth lead of the megger should be dipped in the water and tested for insulation carried out in the same manner as described above.

Continuity Test : For star/delta-connected motors (having six emerging leads) connect one lead of megger to the red lead of connecting cable and the other to red lead of cable the reading should be zero. Check similarly between the blue leads and yellow leads.

For delta connected motors (having three emerging leads) connect one lead of megger to red and the other to yellow and continuity will be indicated. The same applies to yellow and blue, and blue and red.

Rotation Check. Without fixing the pump connect the motor to the starter. Pour some water at the top on the oil-seals in the motor adaptor. Turn on and allow the motor to run for a second. The direction of rotation should be anti-clockwise when viewed from the top of the motor. To avoid serious damage, do not run dry motor without filling.

Coupling of Pump and Motor. Put the sand collar in position on the motor shaft. The key slot provided on the motor shaft should be in line with the key slot in the sand collar. Fit the key in position and then the coupling on the motor shaft.

Clean the lower face of the pump adaptor with kerosene. Fix a small length delivery pipe to the pump with the help of chain spanners after applying thread-compound on the threads. Fix installation-clamp under pipe coupling provided at the other end of the pipe. Lift the assembly with the help of chain/wire sling, taking care that its position is exactly vertical.

Position the motor under the pump, so that the motor and pump shafts are in line. Lower the pump on to the motor. The key-slot on the pump shaft should be aligned with key-slot in the coupling. The pump shaft should enter the coupling fitted with key easily. The register on the pump adaptor should go into position in the recess in the motor adaptor. Tighten the four cap screws after aligning the holes in the pump adaptor and the motor adaptor. To avoid damaging of discharge outlet, do not exert too much pressure on riser pipe.

Using clamps to support the weight of the pump on the top of the casing, thread the required lengths of riser pipes so as to obtain the desired setting. The first piece of riser pipe should not be longer than 1.5 m. After tightening the first piece of riser pipe, tighten the two screws on the non-return valve to lock the pipe in position. Strap the submersible cable to riser pipe, using stainless steel/brass bands and clips at 3 m interval. The submersible cable must be protected by rubber cable guards, sheet lead or other means, at those sections of the cable where it is necessary to prevent the insulation from being damaged by cutting or pinching.

While lowering the pump into the well, allow cable to feed off reel, taking care not to allow insulation to be damaged by dragging over the casing edge. Special care should be taken to keep the wire free, when a pipe clamp or holder is fitted on the well casing, to prevent pinching or breaking of the wire.

If the cable insulation is damaged or cut, the cable should be cut and repaired before continuing installation, cut the insulation as instructed under splicing instructions and install a connector. Tape the overlapping ends of the cable insulation with PVC electrical tape over 2.5 cm on each end. Follow the same procedure as outlined in cable splicing.

Depth of Pump in the Well : The depth of submergence depends upon the drawdown of the well and as a general rule the depth of setting should be at least 3 m below the lowest drawdown level. Under no circumstances should the pump be set on the bottom of the well or in sand or mud.

Installing the Discharge Elbow : After installing the last riser pipe, screw the discharge elbow or bend to the top end of the pipe. Thread the cable through the opening provided for the cable and lower the discharge elbow into position on the top of the casing.

Check all leads with megger to ground. Use riser pipe for ground connection of megger. Readings should be from 2 megohms to infinity if the cable insulation has not been damaged; if readings lower than 2 megohms are obtained, the cable insulation has been damaged or the splice between motor leads and submersible cables is not satisfactory; the unit should be pulled out and cable or splice damage repaired before attempting to start the unit. Readings below 1000 ohms per volt will result in serious damage to the motor and control equipments, if any attempt is made to start the pump under this condition.

Motor Control :

- It is desirable to have a starter on the line with magnetic and thermal overload relays of suitable rating.
- It is important to have a single-phasing preventer connected to the line to avoid any damage to the motor.
- An ammeter with selector switch and a voltmeter should preferably be connected to the circuit.

Rinsing : Fill and empty the motor by opening and closing the drain plug provided at the bottom, at least three times. Third time shake the motor to rinse the inside space, before finally draining the water through drain plug. Fill the motor in vertical position slowly, so that all air pocket are vented out and motor is filled to the brims. Put the coupling on sand guard with its circular groove on top. Similarly after washing the pump, lift it vertically and slowly lower it on to the motor studs, taking care that cable guards are matched with the cable. Tighten the nuts evenly so that no distortion takes place. The pump rotating assembly when levered at the coupling with a screw driver should lift slowly indicating that the alignment of pump and motor is correct.

Now the insulation and continuity of motor should be checked with megger. Remove the brass screw from drain plug and pump water with help of rubber pump, keeping the other end of rubber pump into a bucket of water. After a few minutes of pumping, water will start coming out from the brass plug provided in the suction casing located at the centre of pumping set.

Clamping : Connect the first length of column pipe with the body of non-return valve and clamp column pipe with supporting clamp. Lower the pumping-set by means of chain pulley block and tripod and go on connecting subsequent pipe lengths. Fix cable clip at every 3 meters of column piping to hold the cable in position. For higher capacity of pumps, the delivery pipe flanges shall be provided with slots for passing this cable. Any pulling or distortion of cable should be avoided, otherwise cable may get damaged. Lower the pump with additional length of pipe till pump reaches the correct level in well. Delivery pipe should not be filled with water when pump is being lowered. Join the bend and the sluice valve at the top.

Operation of Pump :

Before Starting the Pump :

- Final megger test is to be taken before connecting the cable leads to the control panel; cable should be connected to the control panel, if final megger test is OK.
- Observe the main switch to ON position; check the voltage; pump should not be started till the rated voltage is obtained.
- Observe the phase indicating lamps; do not start the pump if the glowing intensity of all the lamps is not the same; do not operate the pump in case of single phasing.
- Ensure perfect earthing by connecting the earthing wire to the delivery pipe.
- Check the direction of rotation. Adopt the following method :
- Close the sluice valve; start the pump, note the pressure gauge reading; interchange any two motor leads and check the pressure gauge reading. Correct direction of rotation shows higher pressure gauge reading.

- In the absence of pressure gauge, observe the discharge at the outlet; interchange the motor leads and observe the discharge again. Discharge is higher when direction of rotation is correct.

Starting the Pump :

- Close the sluice valve leaving small gap for air escape.
- Start the pump, let the motor pick up full speed, open the delivery valve fully.
- If the first discharge contains dirt or sand, do not open the valve fully. Wait till clear water starts flowing. Then open the valve slightly more, if the discharge gets dirty again lighten the valve to the original position and wait for some more time. Repeat this procedure till there is a continuous flow of clear water. Do not stop the pump till the above result is obtained.

Check the following points while running :

- Whether pumps is running smooth (check vibration and noise).
- Whether power consumption is within the limits (check voltage and current).
- Pressure gauge readings

5.6.3 Check Chart for Vertical Turbine Pumps : Causes of trouble and suggested remedies :

Pump Not Starting :

- 1. Faulty wiring of motor :**
 - Check current characteristics with data on motor name plate.
 - Check wiring with diagram and data on motor name plate.
 - Be sure starter is properly connected and correct for wattage and voltage.
 - Check fuses or circuit breaker for open power line.
 - Reset starter overload relays, if tripped.
 - Check remote-control stations for possible open circuit.
 - If motor fails to operate independently of pump with all wiring correct, call motor manufacturer's service engineers.
- 2. Excessive bearing friction :**
 - Use oil of viscosity between of 100-150 SSU at pumping temperature on enclosed shaft of oil lubricated pumps. Lubricate all bearings before operation.
 - Be sure enclosing-tube stabilizers are properly located in column assembly.
 - In oil-lubricated pumps, lack of proper tension on the shaft-enclosing may allow misalignment of the bearings. Be sure that tube tension nut is tight.
 - Rubber bearings in water-lubricated units may seize if dry. Lubricate before starting.
 - Bent shafts must be replaced.
 - A crooked well causing misalignment must be straightened or a pump of small enough diameter should be installed to hang freely in the well.
 - Check for misalignment caused by crossed threads, or burred or dirty dowel fits on finished surfaces. Align head centre line with pump centre line. Improper anchoring of head can cause distortion and bending of pump.
- 3. Incorrect impeller adjustment :** Set impellers high enough to allow for shaft stretch due to hydraulic thrust. When adjustment allows shaft to turn freely, stretch caused by shaft and motor weight have been taken care of additional clearance may be necessary to allow for shaft stretches during pumping caused by hydraulic thrust. Charts are available to calculate compensating adjustment required. If adjustment is too high, impellers may rub.

4. Impellers locked :

- Sand locking is common. Sometimes raising and lowering impellers by the adjusting nut frees them. Backwashing with clear water may help. Careful use of the right type wrench on the shaft top may free the impellers. When these methods fail, pull the pump and dismantle the bowl assembly to free the impellers.
- Corrosion, graphitization or bacterial growth may lock the rotating element. This is especially true if the pump has been idle for long period in brackish or acid water. Barnacle accumulations under similar condition in sea water pumps have the same effect.
- Obstructions such as pieces of wood, rags, or metal may prevent rotation. Dismantle and remove the obstructions. A suction strainer helps to guard against this.

5. **Packing too tight :** Normally, packing should be adjusted to allow a slight leakage for cooling and lubrication.

6. Other causes :

- Pump is frozen
- Well has collapsed.
- Earthquake or other force may cause serious misalignment. Check for these and adopt the necessary remedial measures.

Pump not Delivering :

1. Pump not Primed :

- Vertical turbine pumps will not start pumping against a suction lift. Be sure that the lowest impellers is submerged.
- On the closed suction pump, be sure that the suction head meets requirements of the unit.
- Vent the wells to atmospheric pressure so that pump should not operate under a vacuum at its suction.

2. **Rotation incorrect :** Correct rotation of the driver. Three phase motor rotation can be changed by transposing any two of the power leads at the motor's terminals or at the switch.

3. Pumping head too high :

- Lowered pumping level (higher lift) or increased pressure on system beyond the pump's discharge can cause a total pumping head higher than that the pump develops.
- Increased discharge-pipe size or reduction in discharge pressure may be necessary. If this is not possible, install a pump that meets existing conditions.
- Be sure that discharge valves are open and check valves are free.

4. **Overpumping the well :** Drawdown, that is, the difference between the static and pumping levels in a well, may lower the pumping level so that the pump breaks suction continuity. This condition can cause serious harm to both pump and well. Throttle the discharge or use other means to reduce pump capacity and prevent overpumping.

5. Pump speed too low, resisting in insufficient head :

- Be sure that frequency and voltage are correct for motor driven units.
- Be sure gear ratio and output speed of prime mover are correct for gear-driven units.
- Check pulley size and prime-mover speed on belt-driven units.
- Be sure pump turns freely and that mechanical troubles are not retarding speed.

6. Suction clogged :

- Make sure that the strainer, suction pipe and impellers are not clogged. Backwashing may clear.
- Well screens may be clogged and required the services of a competent well man.

7. Mechanical failure :

- Check for broken shaft and replace if necessary.
- Make sure none of the impellers are loose.
- All column-pipe joints must be tight to eliminate excessive leakage.
- Check bowl assembly and make sure it is not broken.

Capacity too low :

1. **Head too high.** Centrifugal-pump performance is such that an increase in head results in a decrease in capacity. Conversely, decreased head increases capacity.

2. **Speed too low**

3. **Poor suction conditions :**

- Pit or sump must have been poorly designed such that liquid velocities and suction submergence are not in accordance with the manufacturer's recommendations. Do not allow turbulence, eddying and vortexing at the pump's suction. Baffling or other modifications may be all that is necessary.
- Aerated or gaseous water has the effect of reducing capacity.
- Check suction piping for air leaks.
- Vent the well properly.
- Be sure that the suction head on closed suction pumps is correct.
- Check for obstructions in strainer, suction pipe and bowls.
- Check for partial clogging of water passages because of corrosion, bacterial growth or other causes.

4. **Leakage :**

- Tighten all pipe threads and flanges.
- Replace worn gaskets or packing.
- Be sure that there are no cracks or holes in column pipe, bowl assembly or discharge head.

5. **Incorrect Impeller Adjustment :** Operating clearances of semi-open impellers must be close. To obtain maximum capacity, be sure impellers are adjusted as close as possible to the bottom of their casings; otherwise, slippage reduces pump capacity.

6. **Mechanical failure :**

- Worn out impellers or wearing rings allow slippage, which reduce capacity. A slight increase in capacity can sometimes be obtained by resetting the impeller adjustment for operation closer to the bowls but if parts are badly worn, replacement is necessary.
- On enclosed-shaft pumps, worn bearings below the relief vent in the end cause reduced discharge capacity.
- Impellers loose on the pump shaft.

7. **Defective test equipment :**

- Make sure that the water level when pumping is accurately determined
- Calibrate pressure-gauge.
- Check accuracy of capacity-measuring devices.

Power Consumption Too Much :

1. **Operating condition different from those for which pump is designed :**

- Check pump curves. If conditions cannot be corrected to reduce power required by the pump, a large motor may be needed.

- Speed of gear or belt-driven pumps can often be reduced to lower the wattage. This also reduced pump capacity and head.
- Diameter of most impellers can be cut down to reduce wattage, which also reduces capacity and head.
- Where there is a wide difference between actual operating and pump design conditions, it may be necessary to change the pump.

2. Rotation Incorrect

3. Speed too high, resulting in over capacity and higher head :

- Reverse practice of that given in too low speed may be adopted.

4. Liquid different from that for which pump is designed :

- Higher specific gravity may require a larger motor.
- Higher viscosities can sometimes be corrected by heating the liquid.
- Air or gas in water can cause cavitation. Increased submergence lower inlet velocity or other suction changes may help in correcting troubles.
- Sand in water may indicate that suction area needs cleaning out. Wells may require new screens or sand pumping to develop water-bearing strata.

5. Impellers rub because of incorrect adjustment.

6. Lubrication incorrect :

- Check for proper quantity and viscosity of oil in oil-lubricated pumps.
- Be sure that liquid is lubricating all bearings in open shaft pumps. Where several bearings may be located between foundation level and an underground elbow, it may be necessary to install an air-release valve in the column to allow to reach all the bearings.
- Be sure that driver bearings are lubricated according to manufacturer's instructions.

7. Packing too tight.

8. Mechanical failure :

- Check for misalignment listed above.
- Make sure bearings are not too tight.
- Remove the cause of vibration if any.

Pump Vibrates :

1. Misalignment. Check for misalignment as listed above.

2. Bearing failure :

- Be sure that lubrication is correct.
- Check for excessive sand in water.
- Correct pump alignment.

3. Poor suction conditions. Correct cavitation defects.

4. Imbalance :

- Operate driver machine (primemover) alone to see if it vibrates.
- Check for foreign materials lodged in impeller or bowl passages. Such materials might cause both static and hydraulic imbalance.
- Check rotating parts for excessive wear. Excessive abrasives in water can change water passages and cause hydraulic imbalance. Wear also changes static balance.

Water in the Shaft-Enclosing Tube

1. Enclosing-tube failure :

- Repair broken or leaking sections.

- Renew broken or loose bearings.
- Be sure that all joints are tight.
- 2. Failure in bowls :
 - Make sure that discharge-case vent is not plugged.
 - Be sure that bearing below vent is not worn or scored, allowing excessive pressure on vent.
 - Check pump shaft for wear that would produce excessive bearing clearance.
 - Be sure that bearing above vent is not worn or scored, allowing any excess leakage to go into enclosing tube instead of through vent.

5.6.4 Pump Failure and Remedies

Sl. No.	Breakdown (Failure)	Check points*
1.	Pump does not deliver	1 7 8 9 10 11 12 14 15 17 18 19 23 25 36 56 57 58
2.	Pump delivers at reduced capacity	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 19 20 21 22 56 57 58
3.	Delivery performance deteriorates	1 3 7 9 10 11 12 13 14 19 20 21 22 23 24 53 57 62
4.	Pump delivers too much	16 56 57 58
5.	Delivery is interrupted	1 2 6 7 8 9 10 11 12 13 14 15 16 19 22 23 25 56 57 58 62
6.	After stopping pump runs in reverse direction	52
7.	Very noisy	1 2 5 6 7 8 11 12 13 15 19 20 22 54 55 56 57 62
8.	Unsteady running of pump	19 20 22 31 32 33 35 36 37 38 39 40 43 44 47 48 49 50 51 54 55 58
9.	Stuffing box leaks excessively	24 27 28 29 30 31 47 48 49 53
10.	Fumes from stuffing box	22 23 24 25 26 27 28 29 30 41 42 43
11.	Pump rotor locked in standstill position	22 45 46 50
12.	Pump is heating up and seizing	23 24 25 26 27 28 29 30 40 41 42 43 46 47 48 49 50 54
13.	Bearing temperature increases	19 20 21 22 31 32 33 34 35 36 37 38 39 40 42 43 44 45 46 47 48 49 51 54 55 58
14.	Motor does not start	14 22 60
15.	Motor gets hot or burns out	14 22 27 28 40 43 50 55 56 57 58 59 60 61
16.	Motor is difficult to start	14 22 27 28 45 46 50 58 59 60

* Check points

1. Suction pipe, foot valve choked.
2. Nominal diameter of suction line too small.
3. Suction pipe not sufficiently submerged.
4. Too many bends in the suction line.
5. Clearance around suction inlet not sufficient.
6. Shut off valve in the suction line in unfavourable position.
7. Incorrect layout of suction line (formation of air pockets).
8. Valve in the suction line not fully open.

9. Joints in the suction line not leak-proof.
10. Air leaking through the suction line and stuffing box etc.
11. Suction lift too high.
12. Suction head too low (difference between pressure at suction connection and vapour pressure too low).
13. Delivery liquid contains too much gas and or air.
14. Delivery liquid too viscous.
15. Insufficient venting.
16. Number of revolutions too high.
17. Number of revolutions too low.
18. Incorrect direction of rotation, (electric motor incorrectly connected leads of phase s on the terminal block interchanged).
19. Impeller clogged.
20. Impeller damaged.
21. Casing rings worn out.
22. Separating of crystals from the flow of pumping liquid (falling below the temperature limit/equilibrium temperature).
23. Sealing liquid line obstructed.
24. Sealing liquid contaminated.
25. Lantern ring in the stuffing box is positioned below the sealing liquid inlet.
26. Sealing liquid omitted.
27. Packing incorrectly fitted.
28. Gland tightened too much/stanted.
29. Packing not suitable for operating conditions.
30. Shaft sleeve worn in the region of the packing.
31. Bearing worn out.
32. Specified oil level not maintained.
33. Insufficient lubrication of bearings.
34. Ball bearings overlubricated.
35. Oil grease quality unsuitable.
36. Ball bearings incorrectly fitted.
37. Axial stress on ball bearings (axial clearance for rotor).
38. Bearings dirty.
39. Bearings rusty (corroded).
40. Axial thrust too great because of worn out casing rings, relief holes obstructed.
41. Insufficient cooling water supply to stuffing box cooling.
42. Sediment in the cooling water chamber of stuffing box.
43. Alignment of coupling faulty.
44. Elastic element of coupling wornout.
45. Pump casing under stress.
46. Pipe line under stress.
47. Shaft runs untrue.
48. Shaft bent.

49. Rotor parts insufficiently balanced.
50. Rotor parts touching the casing.
51. Vibration of pipe work.
52. Non-return valve gets caught.
53. Contaminated delivery line.
54. Obstruction in delivery liquid.
55. Delivery flow too great.
56. Pump unsuitable for parallel operation.
57. Type of pump unsuitable.
58. Incorrect choice of pump for existing operating conditions.
59. Voltage too low/power supply over-loaded.
60. Short circuit in the motor.
61. Setting of starter of motor too high.
62. Temperature of delivery liquid too high.

Table - 1
Guideline for Water Requirements for Various Occupancies and Facility
Groups in Litres Per Capita Per Day (LPCD)

Class of Occupancy	Occupancy Groups	For full facilities(LPCD) (LPCD)	For Restricted facilities
A. Residential*	Single Family Dwelling	400	135
	Flats or Apartments	225	135
	Mess Hostels or Boarding House	135	70
	Minimum Standard Housing	-	70
	Hotels or Lodging House (Per bed)	300	135
B. Educational*	Educational Facilities	70	45
	Pre school Facilities	50	35
C. Institutional	Institution of Children's Care	180	100
	Custodian Institution for Capable	180	100
	Custodian Institution for Incapable	120	70
	Penal and Mental Institution	120	70
D. Health Care*	Normal Medical Facilities	450	225
	Emergency Medical Facilities	300	135
E. Assembly	Large Assembly with fixed Seats (per seat).	90	45
	Small Assembly with Fixed Seat (per seat)	90	45
	Large Assembly without Fixed Seat**	8	5
	Small Assembly without Fixed Seats	8	5
	Sports facilities	8	5
F. Business and Mercantile	Offices	45	30
	Small Shops and Markets	45	30
	Large Shops and Markets	45	30
	Garage and Petrol Stations	70	45
	Essential Services	70	45

Class of Occupancy	Occupancy Groups	For full facilities(LPCD) (LPCD)	For Restricted facilities (LPCD)
G. Industrial	Low Hazard Industries	40	25
	Moderate Hazard Industries	40	25
H. Storage	Low Fire Risk Storage	10	6
	Moderate Fire Risk Storage	10	6
I. Hazardous	Explosive Hazard Building	8	8
	Chemical Hazard Building	8	8
K. Miscellaneous***	Private Garage & special Structure	8	5
	Fences, Tanks and Towers	.	3

* For full facility in occupancy classification A,B, and D the water requirement value includes 25% hot water.

** In the case of mosques, the water requirements given above shall be adequate for ablution and other uses of one devotee per prayer. The appropriate LPCD value may be calculated on this basis.

*** Water requirement for occupancy K is shown as a provision for unknown visitors only.

5.7 Storage Temperature

The design of hot water supply system may be based upon the following temperature requirement:

Scalding	68°C
Hot bath	41°C
Warm bath	37°C
Tepid bath	30°C
Sink	60°C

5.8 Storage Capacity of hot water

The capacity of hot water vessel shall be based on the maximum short time demand of the premises.

5.9 Hot water Heater

The hot water heater shall conform to the following standards BS 758, BS 779, BS843, BS 855, BS 1250, BS 2883

5.10 Cold Water supply connection to Water Heaters.

The connection of Cold water supply piping into water heater shall be made near its bottom. The minimum size of cold water supply piping shall be based on the probable hot water demand of different fixtures but not less than 25mm. The supply pipe shall deliver cold water into hot water cylinder as follows:

- The water heater (electric or gas) of less than 15 Litres storage capacity may be directly connected to the water main through a nonreturn valve.
- The storage heater of 20 to 70 litres capacity may be connected directly to the water main through a nonreturn valve and with an additional device that will prevent the siphonage of hot water back to the water main.
- The enclosed water heater with storage capacity greater than 70 litres shall be fed from the storage tank.

This water heater not be connected directly to the water main.

- The water supply connection to an open vessel type water heater may be made with an air gap of at least 15mm above the top edge of the water heater. Ball valve connection shall not be used to control the flow of water into this water heater.

5.11 Design consideration of hot water piping :

The design consideration of hot water piping shall be such that hot water will appear quickly at the outlet of different fixtures. To improve the situation, a secondary circulation system with flow and return pipe from and to the hot water cylinder may be adopted.

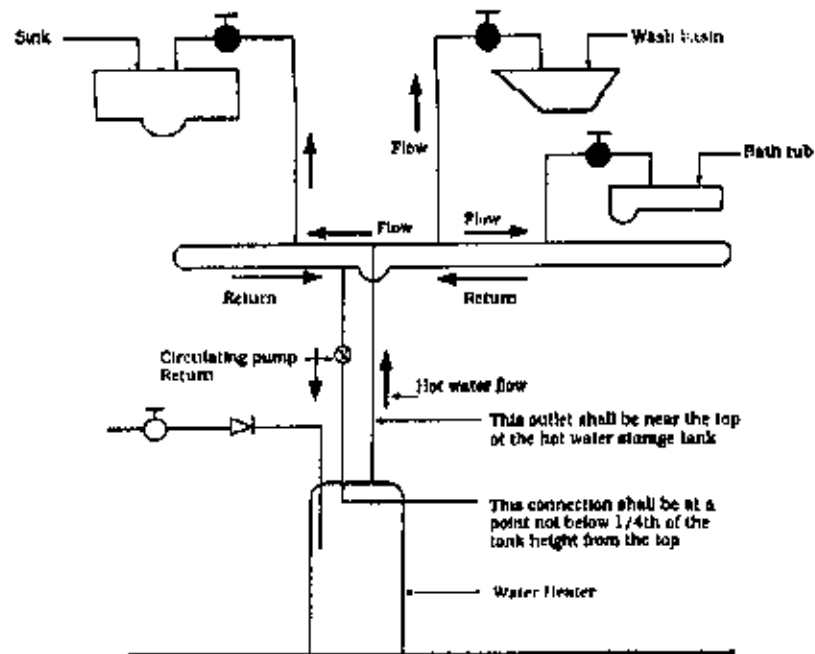


Fig. - 4 Hot water secondary circulation system

5.12 Vent Pipe

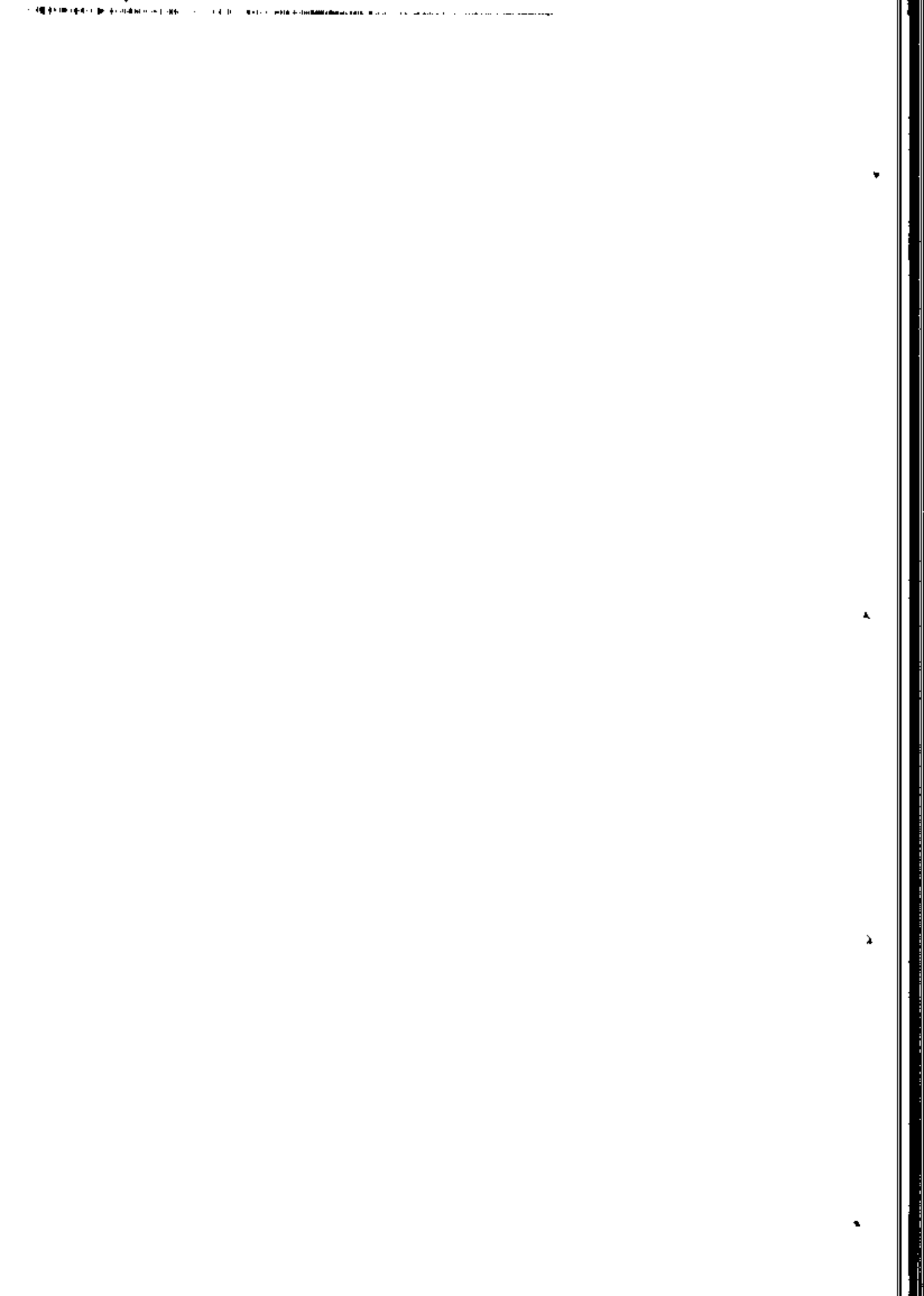
The pressure type hot water heater shall be provided with a vent pipe of not less than 19mm diameter. The vent pipe shall rise vertically above the water line of cold water tank by at least 150mm plus 1mm for every 30 mm height of waterline above the bottom of the water heater.

The vent pipe shall be connected to the top of the hot water cylinder. The vent pipe may be used to supply hot water to the point in between the cold water tank and the hot water cylinder. The vent pipe shall not be provided with any valve or check valves.

The termination of vent pipe shall be such as not to cause any accidental discharge to hurt or scald any passerby or person in the vicinity.

5.13 Safety Device for storage of hot water.

The temperature relief valve or pressure relief valve or a combination of temperature and pressure relief valves shall be installed for the equipment for heating or storage of hot water. The temperature relief valve shall be set at a maximum temperature of 99°C. The maximum pressure rating of water heater shall not be more than 1000kPa. The temperature relief valve shall be placed directly above cylinder it serves but in no case more than 75mm away from the cylinder. The location of pressure relief valve shall be closed to the equipment it serves. There shall be no valve connection in between a relief valve and the water cylinder it serves.



Appendix - B

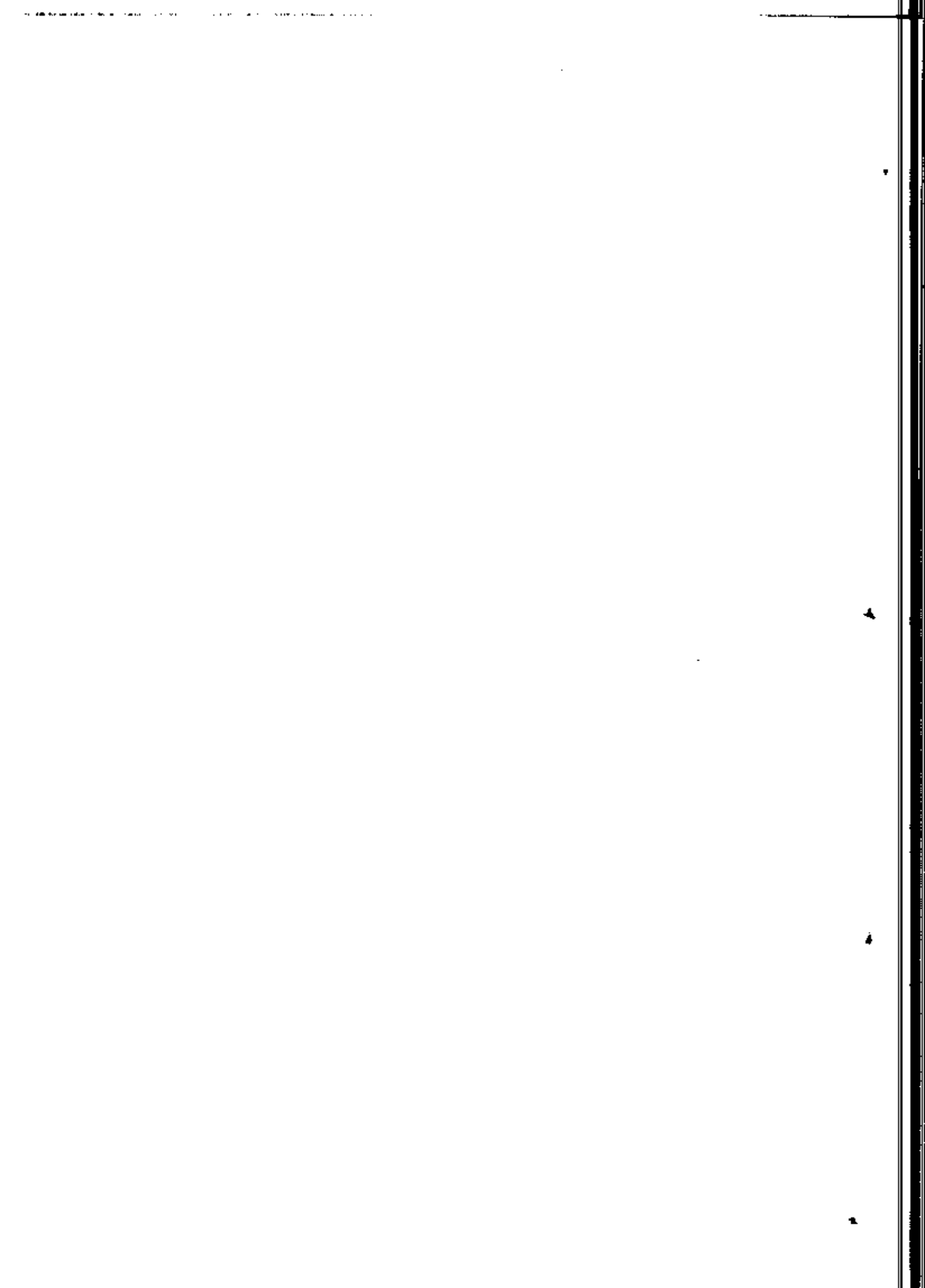
Loss of Head (in feet) Due to Friction in Pipes (Per 100 Ft. of 15-Yr. -Old Iron Pipe)

(For new and smooth iron pipe use 0.71 of value shown in table)

Gallons per Minute	1/2" Pipe		3/4" Pipe		1" Pipe		1 1/4" Pipe		1 1/2" Pipe		2" Pipe		2 1/2" Pipe		3" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
1	1.05	2.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	2.10	7.4	1.20	1.9	-	-	-	-	-	-	-	-	-	-	-	-
3	3.16	15.8	1.80	4.1	1.12	1.26	-	-	-	-	-	-	-	-	-	-
4	4.21	27.6	2.41	7.5	1.49	2.14	0.88	0.57	0.63	0.26	-	-	-	-	-	-
5	5.26	41.0	3.01	10.5	1.86	3.25	1.07	0.84	0.79	0.39	-	-	-	-	-	-
10	10.52	167.0	6.02	38.0	3.72	11.70	2.14	3.05	1.57	1.43	1.02	0.50	0.65	0.17	0.45	0.07
15	-	-	9.02	80.0	5.60	25.00	3.20	8.50	2.36	3.00	1.53	1.00	0.88	0.36	0.68	0.15
20	-	-	12.03	138.0	7.44	42.00	4.29	11.10	3.15	5.20	2.04	1.82	1.31	0.61	0.91	0.25
25	-	-	-	-	9.30	64.00	5.35	16.60	3.94	7.80	2.55	2.73	1.63	0.92	1.13	0.38
30	-	-	-	-	11.15	89.00	6.43	23.50	4.72	11.00	3.08	3.84	1.96	1.28	1.36	0.54
35	-	-	-	-	13.02	119.00	7.51	31.20	5.51	14.70	3.57	5.10	2.20	1.72	1.59	0.71
40	-	-	-	-	14.88	152.00	8.58	40.90	6.30	18.80	4.08	6.60	2.51	2.20	1.82	0.91
45	-	-	-	-	-	-	9.55	50.00	7.08	23.20	4.50	8.20	2.84	2.68	2.05	1.15
50	-	-	-	-	-	-	10.72	60.00	7.87	28.40	5.11	9.90	3.27	3.32	2.27	1.38
56	-	-	-	-	-	-	15.01	113.00	11.02	53.00	7.15	18.40	4.58	6.29	3.18	2.57
100	-	-	-	-	-	-	-	-	14.17	84.00	9.19	29.40	5.88	9.80	4.09	4.08
120	-	-	-	-	-	-	-	-	15.74	102.00	10.21	35.80	6.54	12.00	4.54	4.86
140	-	-	-	-	-	-	-	-	18.89	143.00	12.25	50.00	7.84	16.80	5.45	7.00
160	-	-	-	-	-	-	-	-	22.04	199.00	14.30	67.00	9.15	23.30	6.35	9.20
180	-	-	-	-	-	-	-	-	-	-	16.34	86.00	10.46	29.00	7.26	11.80
200	-	-	-	-	-	-	-	-	-	-	18.38	107.00	11.76	35.70	8.17	14.80
220	-	-	-	-	-	-	-	-	-	-	20.42	129.00	13.07	43.18	9.08	17.80
240	-	-	-	-	-	-	-	-	-	-	22.47	154.00	14.38	52.00	9.99	21.30
260	-	-	-	-	-	-	-	-	-	-	24.51	182.00	15.69	61.00	10.89	25.10
280	-	-	-	-	-	-	-	-	-	-	26.55	211.00	16.99	70.00	11.80	29.10
300	-	-	-	-	-	-	-	-	-	-	-	-	18.30	81.00	12.71	33.40
	-	-	-	-	-	-	-	-	-	-	-	-	19.81	92.00	13.62	38.00

Vel = Velocity feet/second

Fric = Friction head in feet

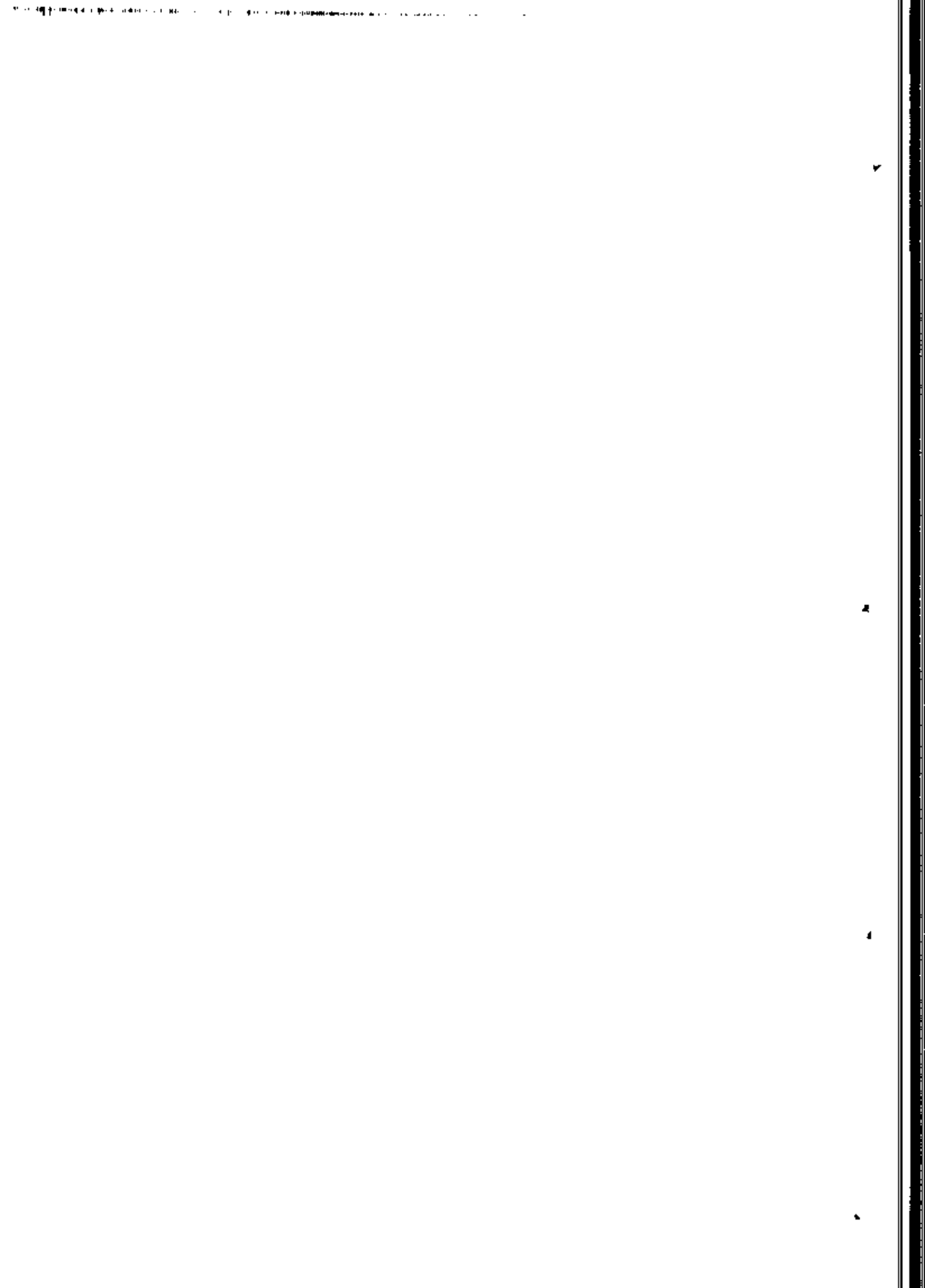


Appendix - C

Loss of Head (in feet) Due to Friction in Pipes (Per 100 Ft. of 15-Yr.-Old Iron Pipe)
(For new and smooth iron pipe, use 0.71 of value shown in table)

Gallons per minute	4" Pipe		5" Pipe		6" Pipe		8" Pipe		10" Pipe		12" Pipe		14" Pipe		16" Pipe		20" Pipe		
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	
40	1.92	0.22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
45	1.17	0.28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
50	1.28	0.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
70	1.79	0.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
75	1.82	0.73	1.14	0.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
100	2.55	1.23	1.22	0.24	1.14	0.14	-	-	-	-	-	-	-	-	-	-	-	-	
120	3.05	1.71	1.96	0.57	1.42	0.25	-	-	-	-	-	-	-	-	-	-	-	-	
125	3.19	1.85	2.04	0.64	1.48	0.28	-	-	-	-	-	-	-	-	-	-	-	-	
150	3.84	2.55	2.45	0.88	1.71	0.32	-	-	-	-	-	-	-	-	-	-	-	-	
175	4.45	3.35	2.66	1.18	2.00	0.48	-	-	-	-	-	-	-	-	-	-	-	-	
200	5.11	4.37	3.27	1.48	2.28	0.62	-	-	-	-	-	-	-	-	-	-	-	-	
225	6.32	5.61	3.67	1.85	2.57	0.74	-	-	-	-	-	-	-	-	-	-	-	-	
250	6.40	6.72	4.08	2.24	2.20	0.92	1.60	0.22	-	-	-	-	-	-	-	-	-	-	
275	7.03	7.99	4.50	2.72	3.06	1.15	1.73	0.27	1.80	0.21	-	-	-	-	-	-	-	-	
300	7.68	9.38	4.90	3.15	3.40	1.29	1.90	0.36	2.04	0.28	1.94	0.25	-	-	-	-	-	-	
350	8.90	12.32	5.72	4.19	3.98	1.69	2.20	0.41	2.25	0.33	2.04	0.29	1.42	0.11	-	-	-	-	
400	10.20	15.82	6.54	5.33	4.54	2.21	2.50	0.56	2.46	0.39	2.13	0.24	1.58	0.13	-	-	-	-	
450	11.50	19.74	7.35	6.55	5.12	2.74	2.92	0.64	2.65	0.45	2.27	0.27	1.79	0.14	-	-	-	-	
475	12.50	22.96	7.88	7.22	5.55	3.21	3.10	0.79	2.85	0.52	2.41	0.31	1.88	0.16	-	-	-	-	
500	12.77	24.08	8.17	8.12	5.60	3.26	3.20	0.81	3.06	0.59	2.56	0.34	1.98	0.18	-	-	-	-	
550	-	-	8.99	9.66	6.16	3.93	3.52	0.98	3.28	0.67	2.70	0.35	2.00	0.16	1.73	0.12	-	-	
600	-	-	9.80	11.34	6.72	4.70	3.84	1.16	3.48	0.75	2.84	0.41	2.10	0.19	1.82	0.14	-	-	
650	-	-	10.62	13.16	7.28	5.50	4.15	1.34	3.68	0.83	3.01	0.45	2.23	0.20	1.91	0.15	-	-	
700	-	-	11.44	15.12	7.84	6.38	4.46	1.54	3.88	0.91	3.13	0.49	2.32	0.21	2.00	0.16	-	-	
750	-	-	12.26	17.22	8.50	7.00	4.80	1.74	4.08	1.01	3.27	0.52	2.41	0.22	2.09	0.17	-	-	
800	-	-	-	-	9.08	7.90	5.12	1.94	4.28	1.11	3.41	0.55	2.52	0.23	2.18	0.18	-	-	
850	-	-	-	-	9.58	8.75	5.48	2.28	4.48	1.21	3.56	0.59	2.62	0.24	2.27	0.19	-	-	
900	-	-	-	-	10.30	10.11	5.75	2.48	4.68	1.31	3.71	0.63	2.72	0.25	2.36	0.20	-	-	
950	-	-	-	-	10.72	10.71	6.06	2.87	4.88	1.41	3.86	0.67	2.82	0.26	2.45	0.21	-	-	
1000	-	-	-	-	11.32	12.04	6.43	3.92	5.08	1.51	4.01	0.71	2.92	0.27	2.54	0.22	-	-	
1100	-	-	-	-	12.50	14.31	7.03	3.51	5.28	1.61	4.16	0.75	3.02	0.28	2.63	0.23	-	-	
1200	-	-	-	-	13.52	16.69	7.67	4.26	5.48	1.71	4.31	0.79	3.12	0.29	2.72	0.24	-	-	
1500	-	-	-	-	-	-	9.63	6.27	6.10	2.09	4.20	0.85	3.15	0.29	2.81	0.25	2.39	0.24	
2000	-	-	-	-	-	-	12.70	10.71	8.10	3.50	5.60	1.43	4.20	0.58	3.64	0.47	3.19	0.39	
2500	-	-	-	-	-	-	-	-	10.10	5.33	7.00	2.18	5.25	1.01	4.55	0.72	3.99	0.56	
3000	-	-	-	-	-	-	-	-	12.10	7.42	8.40	3.39	6.30	1.57	5.48	1.12	4.78	0.80	

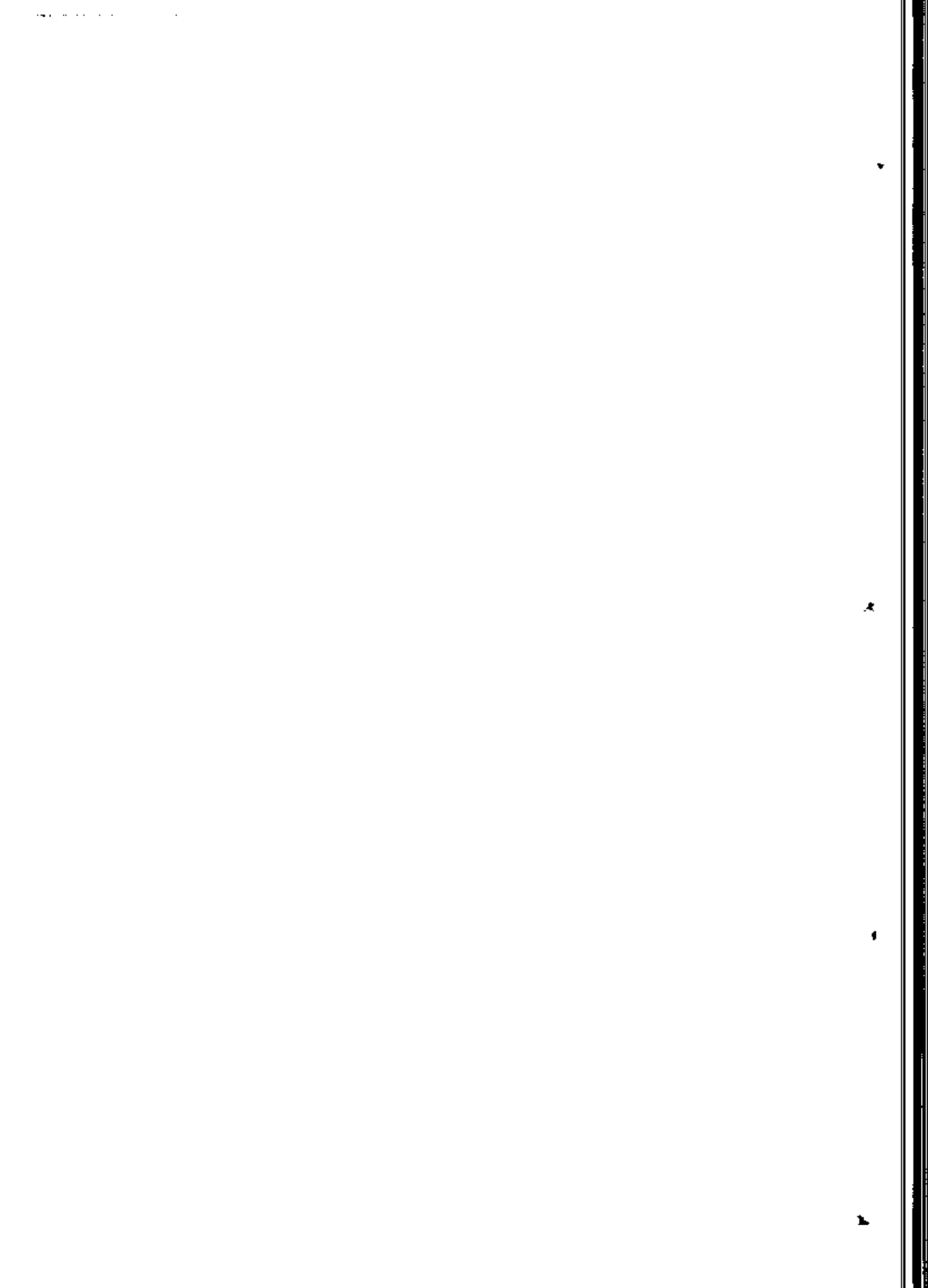
vel- velocity feet second. Fric-Friction head in feet.



Appendix - D

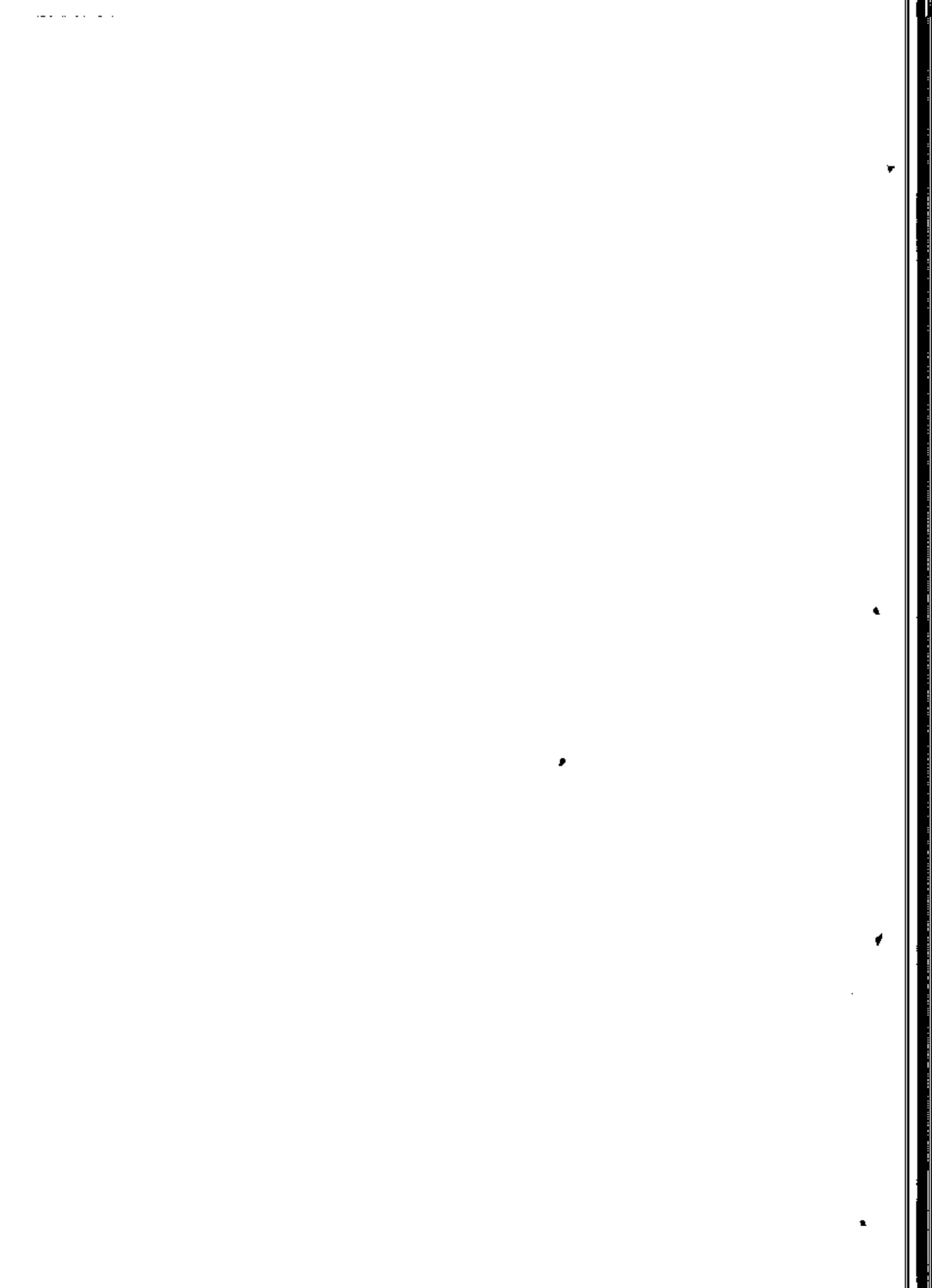
Friction of water in 90° Elbows

Size of Elbow, Inches	Friction Equivalent Feet Straight Pipe
1/2	5
3/4	6
1	6
1 1/4	8
1 1/2	8
2	8
2 1/2	11
3	15
4	18
5	18
6	18
8	24
10	30
12	40
14	54
18	55
20	70



Loss of Head Due to Friction

Gallons per Min. Delivered	Loss of Head in Feet in Various Sizes of Smooth 90° Elbows					Gallons per Min. Delivered	Loss of Head in Feet per 100 Feet of Smooth Pipe					
	Pipe Sizes, Inches-Inside Diameter						Pipe Sizes, Inches-Inside Diameter					
	1	1 1/4	1 1/2	2	2 1/2		3	1	1 1/4	1 1/2	2	2 1/2
20	2.52	0.89	0.42	0.146	0.067	0.038	42.0	11.1	5.2	1.82	0.61	0.25
25	3.84	1.33	0.62	0.218	0.101	0.057	64.0	16.6	7.8	2.73	0.92	0.38
30	5.44	1.88	0.88	0.307	0.142	0.083	89.0	23.5	11.0	3.84	1.28	0.54
35	7.14	2.50	1.18	0.408	0.189	0.107	119.0	31.2	14.7	5.10	1.72	0.71
40	9.12	3.20	1.50	0.528	0.242	0.137	152.0	40.0	18.8	6.60	2.20	0.91
45	-	4.00	1.86	0.656	0.308	0.173	-	50.0	23.2	8.20	2.80	1.15
50	-	4.80	2.27	0.792	0.365	0.207	-	60.0	28.4	9.90	3.32	1.38
70	-	9.04	4.24	1.430	0.683	0.286	-	113.0	53.0	18.40	5.21	2.57
75	-	-	4.60	1.670	0.781	0.458	-	-	60.0	20.90	7.10	3.05
90	-	-	6.72	2.320	0.951	0.600	-	-	84.0	29.40	9.81	4.01
100	-	-	8.16	2.880	1.320	0.744	-	-	102.0	35.80	12.00	4.95
125	-	-	-	4.320	2.060	1.140	-	-	-	54.00	18.20	7.60
150	-	-	-	6.080	2.810	1.560	-	-	-	76.00	25.50	10.50
175	-	-	-	8.160	3.720	2.100	-	-	-	102.00	33.80	14.00
200	-	-	-	10.320	4.740	2.670	-	-	-	129.00	43.10	17.60
250	-	-	-	-	7.260	4.080	-	-	-	-	56.00	27.20



LIFT INSTALLATION

- 6.1 **Provision in Bldg :** For the purpose of effective installation of lifts escalators working drawings showing the layout of lifts & escalator properly identified in the drawing details of building works for example holes and/or punches in floors or walls and supports for lifts shall be prepared prior to the finalisation of building design drawing.
- Necessary particulars of electrical requirement of lifts shall be determined early in the planning stage to include it in the electrical provision of the building.
- 6.2 **ESSENTIAL REQUIREMENTS FOR LIFTS :**
- Lifts shall be provided in buildings more than six storeys or 20m in height.
- 6.2.1 **Stretcher facility in lifts :**
- (a) When passenger lifts are installed in any building having more than ten storeys or a height of more than 32m, each floor served by these lifts must have access to at least one lift with a stretcher facility.
- (b) A lift required to have a stretcher facility shall accommodate a raised stretcher with a patient lying on it horizontally by providing a minimum inside platform area 1275mm wide x 200mm long with a minimum clear opening width of 1050mm unless otherwise designed to provide an equivalent facility, to allow the entrance and exit of an ambulance stretcher (minimum size 600mm wide x 2000mm long) in its horizontal position. These lifts shall be identified by the internationally recognised symbol for emergency medical services.
- (c) In any multi-storied hospital and health care building there shall be at least one hospital lift having stretcher facility in accordance with section (b) above.
- 6.2.2 **Standby power :**
- a) One or more lifts shall be provided with standby power in
- i) A building which has more than ten storeys or a height of more than 32m.
 - ii) Hospital and health care buildings.
- b) Standby power shall be provided by an approved self contained generator set to operate automatically whenever there is a disruption of electrical power supply to the building.
- c) The operation of the standby power system shall be as follows :
- i) Where only one lift is installed, the lift shall transfer to standby power within 60 seconds after failure of normal power.
 - ii) Where two or more lifts are controlled by a common operating system, all lifts may be transferred to a power within 60 seconds after failure of normal power, or if the standby

power source is of insufficient capacity to operate all lifts at the same time, all lifts shall be transferred to standby power in sequence, shall return to the designated landing and discharge their load. After all lifts have been returned to the designated landing at least one lift shall remain operable from the standby power.

6.2.3 Conformity with Bangladesh Electricity Act :

All electrical work in connection with electrical lifts shall be carried out in accordance with the provisions of the latest Bangladesh Electricity Act and the provision of any of its bye-laws and regulation and shall also comply with the requirements of this book.

6.2.4 Safety Considerations :

Fire Protection :

- a) Necessary provisions shall be kept to prevent spread of fire through the lift well. Adequate measures shall also be taken to reduce the possibility of spread of fire from the machine room into the lift well.
- b) Lift well enclosures and machine room shall be constructed with fire resistant materials. In case of fire, the lift well enclosure shall not give off harmful gas or fumes.
- c) Where lift enclosures are fire rated, manually closing doors at the enclosure well shall have a fire rating equal to that of the enclosure well and automatically closing doors shall have a fire rating equal to one-half of that of the enclosure well.

Warning signs against use of the lifts during a fire shall be displayed near every call button for a passenger lift.

Permanent warning sign above each push button on each floor landing shall be "IN FIRE EMERGENCY, DO NOT USE LIFT, USE EXIT STAIRS".

Efficient automatic devices shall be provided and maintained in each lift to stop the car by suitable braking devices and to cutoff power from the motor whenever excessive descending speed is attained.

Efficient automatic devices shall be provided and maintained in each lift to cut off power from the motor if the car over travels either the top or bottom terminal landing.

There shall have standard cranking system operable from the lift machine room to move the car manually, during a power failure, to the nearest higher or lower landing for evacuation of passengers.

There shall have arrangement for emergency unlocking of the landing and lift door with a special key from any landing for evacuation as well as for maintenance.

Necessary protection shall be taken against breaking of steel rope.

6.2.5 Lift Cars.

There shall be provisions for elastic isolators between metal parts to ensure low vibration and low noise during car travel.

The floor shall be a smooth nonslip surface. If carpeting is used, it shall be securely attached, heavy duty, with a tight weave and low profile, installed without padding.

A handrail shall be provided on at least one wall of the car, preferably the rear. The rails shall be smooth and the inside surface at least 38mm clear of the walls at a nominal height of 800mm from the floor.

Height of the entrance to the lift car shall not be less than 2m.

The lift car doors, shall be power operated horizontally sliding type (noncollapsible), opened and closed by automatic means. However, if space is limited, collapsible doors may be installed in case of buildings not exceeding 8 storeys or 26m in height, but they shall not be power operated. Sliding doors shall be guided at top and bottom. Means shall be provided to prevent all sliding

doors from jumping off the tracks and suitable stops shall be provided to prevent the hanger carriage from leaving the end of the track.

Car and landing doors shall open and close in full synchronization being mechanically connected to each other.

Doors closed by automatic means shall be provided with door reopening device(s) which will function to stop and reopen a car door and adjacent landing door in case the car door is obstructed while closing. The reopening device shall also be capable of sensing an object or person in the path of a closing door without requiring contact for activation. Door reopening devices shall remain effective for a period of not less than 20 seconds. The operating mechanism for the car door shall not exert a force more than 125 N.

Lift car doors, when closed shall cover the opening except in the case of vertical biparting car doors of goods lifts. Car doors shall be equipped with efficient interlocking or other devices so that the door cannot be opened except when the lift car is at the landing and that the lift car cannot be moved away from the landing until the leading edge of the single slide or double slide door is within 50mm of the nearest face of the door jamb or the leading edges of the centre opening doors are within 50mm of contact of each other.

The lift car shall be provided with a self leveling feature that will automatically bring the car to the floor landing within a tolerance of $\pm 13\text{mm}$ under normal loading and unloading conditions. The self-leveling shall, within its zone, be entirely automatic and independent of the operating device and shall correct the overtravel or undertravel. The car shall also be maintained approximately level with the landing, irrespective of load. Where no self-leveling device is provided, the leveling difference between the car and the landing shall be within

$\pm 40\text{mm}$.

Car operating panels shall be conveniently located on the side near the door so that passengers can register calls as quickly as possible. The centreline of the alarm button and emergency stop switch shall be at a nominal height of 890mm, and the highest floor button no higher than 1.37m from the floor registration buttons, exclusive of border, shall be a minimum of 18mm in size, raised, flush or recessed. Visual indication shall be provided to show each call registered and extinguished when the call is answered. Depth of flush or recessed buttons when operated shall not exceed 10mm. Markings shall be adjacent to the controls on a contrasting colour background to the left of the controls; letters or numbers shall be a minimum of 15mm high and raised or recessed 0.75mm. Sign plates permanently attached shall be acceptable. Emergency controls shall be grouped together at the bottom of the panel.

A suitable battery operated alarm system shall be installed inside the lift car so as to raise an alarm at a convenient place for getting assistance for passengers trapped inside the lift car.

A car position indicator shall be provided above the car operating panel or over the opening of each car to show the position of the car in the lift well by illuminated visual indicator corresponding to the landing which the car is stopped or through which it is passing.

In addition an audible signal shall preferably be installed which shall sound to tell a passenger that the car is stopping at a floor served by the lift. A special button located with emergency controls may be provided, operation of which shall activate an audible signal only for the desired trip.

In installations with more than two lifts in a bank, a telephone or other device for two-way communication between each lift car and a convenient point outside the lift well shall preferably be provided. Markings or the international symbol for telephones shall be placed adjacent to the control a contrasting colour background.

6.2.6 Lift well and lift well Enclosure

The lift well shall only be used for housing equipment forming part of the lift installation or for its operation and maintenance. No other equipment or services shall be accommodated therein. For this purpose, the main electric supply line for lift machine shall be deemed to be part of the lift and the electric cable, if laid along the lift well shaft, shall be properly clamped to the wall.

The lift well shall not form part of the ventilation system of the building.

In multi-story residential buildings, hotels, and hospitals, lift well shall be isolated from sleeping room (bed rooms) by lobbies or other spaces.

Lift well shall not be located above any room, passage or thoroughfare. However, when absolutely necessary, this can only be permissible with the prior approval of the competent authority and in such case the following provisions shall be made.

- a) The pit shall be sufficiently strong to withstand the impact of the lift car with the rated load or the impact of the counterweight when either of these is descending at the rated speed or at governor tripping speed;
- b) Spring or oil buffers shall be provided for lift car and counterweight; and
- c) The car and counterweight shall be provided with a governor operated safety gear.

When there are three or fewer lift cars in a building, they may be located within the same lift well enclosure. When there are four lift cars, they shall be divided in such a manner that at least two separate lift well enclosure are provided. When there are more than four lifts, not more than four lift cars may be located within a single lift well enclosure.

The lift car and its counterweight shall travel just opposite to each other.

6.2.7 Landing Doors

Every landing, where there is access from the landing to the lift car, shall be fitted with a landing door. Such door shall be fitted with efficient interlocking or other devices so as to ensure that the door cannot be opened except when the lift car is at the landing and that the lift car cannot be moved away from the landing until the door is closed and locked. Where mid bar collapsible doors are used for landing entrance, they shall not be power operated.

No automatic fire door or shutter which operates by means of a fusible link or otherwise due to the action of heat shall be allowed in any landing opening or liftway enclosure of any lift, if such opening gives access to any exit from the building.

In case of passenger lifts, solid sliding doors shall preferably be provided for buildings above six storeys or 20m in height. Solid swing doors may also be used where sliding space is not available parallel to the entrance door. Collapsible doors shall not be provided in case of building above eight storeys or 26m in height.

6.2.8 Guide Rails

Car and counterweight guide rails shall be continuous throughout the entire length right from the bottom of the pit floor to the top most floor served plus additional length as may be required for operation of safety against over run. They shall be provided with adequate brackets or equivalent fixing devices of such design and spacing that the rails shall not deflect more than 4mm under normal operations.

For passenger and goods lifts having a rated speed of 0.5 m/s or more, the car guide rails shall have working surfaces machined and smooth.

6.2.9 Lift Pits :

Lift pits shall be of sound construction and shall be maintained in dry and clean condition. Where necessary, provision shall be made for permanent drainage.

Lift pits having depth more than 1.6m shall be provided with a suitable descending arrangement to reach the lift pit.

Light points shall be provided in all lift pits for facility of repair and maintenance works.

In case of a group of two or more lift wells, arrangements shall be provided to allow inspection of a lift pit through the adjoining one.

Table - 1
Minimum Pit Depths for Traction Lifts - Overhead Machines

Speed (m/s)	0.5	1	1.5	2	2.5	3	3.5	4
Depth (m)	-	-	-	1.6	2.6	2.8	3.0	3.2
i) With restrained rope compensation	-	-	-	-	-	-	-	-
ii) With chain, free rope or travelling cable compensation.	1.5	1.5	1.6	2.4	2.5	-	-	-
iii) With reduced stroke buffer and either restrained rope chain travelling cable or free rope compensation.	-	-	1.5	1.6	2.4	2.6	2.6	2.8

6.2.10 Buffers

Buffers of spring or oil shall be used for safety. Buffers shall be fitted under the lift car and counterweight directly or on the pit floor with suitable concrete or steel foundation. Oil resistant rubber buffers may be used with lifts having a rated speed not exceeding 0.25 m/s. Lifts having rated speed in excess of 0.25 m/s and up to and including 1.0 m/s spring or oil buffers shall be used. For lifts having rated speed more than 1.0 m/s only oil buffers shall be used. Wooden blocks suitably treated may also be used for service lifts for speeds upto 0.5 m/s. Buffers shall be located symmetrically with reference to the vertical centreline of the car/counterweight with a tolerance of 50mm.

6.2.11 Machine Room and Overhead Structures

The lift machine room shall only be used for housing lift machinery controller and other associated apparatus and equipment. No other services or equipment shall be accommodated therein. If motor, generators and other associated equipment are installed in an adjoining room, this room shall also be reserved for exclusive use of lift equipment.

Lift machine room and other associated equipment rooms shall be fire proof, weather proof and adequately lighted. Means to prevent spread of fire or smoke from machine room into lift well shall be provided. Machine room shall have permanent ventilation opening direct to the open air having a free area not less than 0.1 m² per lift.

The height of the machine room shall not be less than 2.30m throughout under the lifting beam (trolley beam) to allow any portion of equipment to be accessible and removable for repair and replacement. An overhead trolley beam of steel construction of adequate strength shall be provided in the machine room, for movement of equipment during installation.

The machine room shall be adequately sized and shall have sufficient floor area required for easy access to all parts of the machines and equipment located therein for purposes of inspection, maintenance or repair. Clearance space of 1m shall be provided on those sides of control panels where maintenance is required to be carried out while the panel is energized, otherwise 0.5m clearance space may be provided.

The room shall be kept closed, except to those who are concerned with the operation and maintenance of the equipment. When the electrical voltage exceeds 220/230V a danger notice plate shall be displayed permanently on the outside of the door and on or near the machinery.

Machine room floor shall not have holes/punches in it except for necessary small openings for passage of ropes cable etc. If any machine room floor or platform does not extend to the enclosing walls the open sides shall be provided with hand rails or otherwise suitably guarded.

All machines, pulleys, overspeed governors and similar units shall be securely fixed on the machine room floor.

Adequate artificial light shall be provided in the machineroom. A 15 amps 3 pin power outlet for hand operated tools and a 5 amps 2 pin electrical outlet for portable hand lamp set shall be provided in the machine room.

Access to Machine Room

- a) The machine room shall be provided with a direct, independent and convenient access. Access to a machine room above a lift well may be either from the roof or by an internal staircase.
- b) Where a machine room entrance is less than 1.5m above or below the adjacent floor or roof surface, a substantial permanently attached ladder may be used.
- c) Where the machine room entrance is 1.5m or more above or below the adjacent floor or roof surface, access shall be provided by means of standard stairs.
- d) Access to a machine room in a basement may be provided from a corridor.
- e) Access to a machine room via the lift well shall be prohibited.

The space at secondary level in which the overhead pulleys, overspeed governors and similar machinery are housed shall have a clear height of at least 1.2m. Where practicable, it shall have a substantial platform or floor and be provided with permanent and adequate artificial illumination. Safe and convenient access to secondary level shall be provided. Means of access between a secondary floor and machine room may be a ladder. Hand rails shall be provided at platform and access to floor.

6.2.12 Hall Buttons, Hall Lanterns and Special Signs.

Hall Buttons

- a) Each landing shall have hall call buttons to register call for lift service for upward or downward movements. The centre line of the hall call buttons shall be at a nominal height of 1m above the floor.
- b) Direction buttons, exclusive of borders, shall be a minimum of 18mm in size, raised, flush or recessed. Visual indication shall be provided to show each call registered and extinguished when the call is answered. Depth of flush or recessed button when operated shall not exceed 10mm.

Hall Lantern

- a) Where lifts are installed in totally enclosed wells, a visual signal shall be provided at each lift well entrance indicating to the prospective passenger the car answering the call and its direction of travel. An audible signal may also be included.
- b) The visual signal may be in the form of digital lift position indicator. The visual signal for each direction/lift position shall be a minimum of 62mm in size and visible from the proximity of the hall call buttons.
- c) The centreline of the fixture shall be located at a minimum of 1.8m from the floor.

6.2.13 Electrical Wiring and Apparatus.

Construction, installation and maintenance of all electrical supply lines and apparatus in connection with lift installation shall be done with proper protection so that there may be no danger to persons therefrom. No bare conductor shall be used in any lift car. Installation of electrical wiring shall conform to the provisions of Chapter "Electrical Installations" in this book.

Electrical circuits for lights and ventilation fans, and supply to 3 pin and 2 pin socket outlets shall be controlled by a separate main switch or circuit breaker and shall be independent of machinery power supply such that lighting circuits remain alive when power to machinery is interrupted.

Suitable cautionary notice shall be affixed near every motor or other apparatus in which energy used is at a voltage exceeding 220 volts.

Travelling Cable

- a) Circuits which supply current to the motor shall not be included in any twin or multi-core travelling cable used in connection with the control and safety devices.

- b) A travelling cable which incorporates conductors for the control circuits shall be separate and distinct from that which incorporates lighting and signalling circuits in case of building ten storeys (32m) or less in height. In case of buildings more than ten storeys or 32 metres in height or where high speed (1.50 m/s or more) lifts are employed, use of a single travelling cable for lighting and control circuits shall be permitted, provided that all conductors are insulated for the maximum voltage in the cables.

Supply Cables and Switches

- a) Each lift shall be provided with a main switch or circuit breaker of a capacity determined by the lift manufacturer and the incoming supply cable shall terminate in this switch. For a single lift, this switch shall be fixed adjacent to the machine room entrance. In a machine room common to more than one lift, each main switch shall be conveniently situated with respect to the lift it controls. Switches and fuses (which may form part of a distribution switch board) shall be provided for isolating the supply power to the machine room.
- b) Where a supply cable serves more than one lift, a diversity factor may be used for the determination of conductor size. The actual diversity factor to be adopted shall be decided by the lift manufacturer.

Earthing

All electrical machinery/equipment viz electric motor, winding machine, control panel etc. which normally carry mains current shall be properly connected to the earthing system. Similarly all metallic cases, covers of door interlinks, door contacts, call and control button, stop buttons, car switches, limit switches, junction boxes and similar electrical fittings which normally carry only the control current shall also be properly connected to the earthing system. All earthing terminal and earthing conductors in this regard shall conform to the requirements of Chapter "Electrical Installation" in this book.

6.3 DESIGN CONSIDERATIONS

6.3.1 Number of Lifts and Capacity

The passenger handling capacity(H) of a lift system for different occupancies in terms of the number of passengers to be handled in the building in a five minute peak period shall not be less than that indicated in Table-2 in this chapter. The average interval shall not be more than shown in table-2 in this chapter.

Table- 2

Maximum Interval and Minimum 5 minute Handling Capacity for Different Occupancy

Type of Occupancy	Maximum interval	Minimum 5 min. passenger Handling Capacity(H)
Diversified Offices	45	10
Diversified Single-purpose offices	45	11
Single-purpose offices	40	12
Hotels and Motels	60	10
Apartments	90	5
Dormitories, Halls of Residence	70	15
Hospitals	50	12
Long term Nursing Facilities	70	8
Educational Institutions	50	25
Assembly	50	15
Shops and stores	50	5

6.3.2 Shape and size of lifts

For the purpose of population estimation, the density of people shall be based on the actual number of occupants, but in no case less than those specified in Table-3. The occupant load of a mezzanine floor shall be taken into account for working out the population for a particular floor to which the mezzanine floor discharges its loads.

Table - 3
Occupant Load for Estimation of Population

Type of Occupancy	Population Factor
Office	
Diversified offices	15m ² net usable area per person (a)
Diversified Single-purpose	13.5m ² net usable area per person
Single-purpose	12m ² net usable area per person
Hotels and Motels	1.7 people per room
Appartments	1.7 people per bedroom
Dormitories, Residence Halls	20m ² net usable area per person
Hospitals	4 people per bed
Long term Nursing Facilities	1.75 people per bed
Education Institutions	4m ² per student
Assembly	
With fixed or movable seats and dance floor	0.60m ² per person ² (b)
Without seating facilities including dining rooms	1.5m ² per person (b)
Shop and stores	2m ² of net selling area (c)

Notes: (a) Net usable area = gross area less lift shaft and lobby space, mechanical space, columns, toilets, corridor around core, air-conditioning machinery space.

(b) Population estimation shall be based on gross area (plinth area or covered area). The gross area shall include, in addition to the main assembly room or space, any occupied connecting room or space in the same storeys or in the storey above and where entrance is common to such rooms and spaces and they are available for use by the occupants of the assembly place. No deductions shall be made in the gross area for corridors, closets or other subdivisions, these shall include all space serving the particular assembly occupancy.

(c) Net selling area is area open to the public.

The car speed for the different types of lifts in different occupancies shall normally be as given in Table-4. A higher or lower speed lift may be used in special cases when conditions warrant use of such lifts.

Table - 4
Car Speed for Lift in Different Kinds of Usage

Type of Lift	Number of Floor	Recommended Car Speed for Different Kinds of Usage (m/s)					
		Office Building (including Professional)	Hotels and Motels	Apartments, Dormitories & Residence Hall	Hospital and Nursing Homes (a)	Assembly	Stores
Passenger Lift	2 to 6	0.75 to 2	0.75	0.75	1 to 2	2	0.75 to 1.5
	7 to 12	2 to 2.5	1.5	1	2 to 2.5	2.5	2 to 2.5
	13 to 20	2.5 to 3	2	2	3.5	3.5	2.5
	21 to 25 (b)	3 to 3.5	2.5	2.5	4	4	-
	26 to 30 (b)	3.5 to 4	3.5	2.5 to 3.5	5	5	-
	31 to 40 (b)	4 to 5	3.5 to 5	-	-	-	-
	41 to 50 (b)	5 to 6	5 to 6	-	-	-	-
	51 to 60 (b)	6 to 7	-	-	-	-	-
	over 60 (b)	9	-	-	-	-	-
Service Lift (C)	2 to 5		1.0				
	6 to 10		1.5				
	11 to 15		2				
	16 to 25		2.5				
	26 to 35		2.5				
	36 to 45		3.5				
	46 to 60		4				
		Over 60		4			

- Notes : (a) For Nursing Homes slower speed lifts may be used
 (b) For buildings of this height, local express lifts shall be used
 (c) Slower speed lifts may be used for heavier loads.

6.3.3 Handling Capacity and interval

A) The handling capacity shall be calculated by the following formula.

$$H = \frac{300 \times Q \times N \times 100}{P \times T}$$

Where

- H = Passenger handling capacity of the lift system during five minute peak period, expressed as the percentage of the estimated total population handled.
 Q = Average number of passengers carried in each car per trip.
 N = Number of lifts in the system.
 P = Total population to be handled during peak period (it is related to the area for which a particular bank of lift serves).
 T = Average round trip time in seconds, that is, the average time required by each lift in taking one full load of passengers from ground floor discharging them in various upper floors and coming back to ground floor for taking fresh passengers for the next trip;

Note :

- 1) The value of Q depends on the dimension of the car. It may be noted that the car is not loaded always to its maximum capacity during each trip and therefore, for calculating T and H the value of Q shall be taken as 80 per cent of the maximum capacity of the car.

- ii) T is the sum of the time required in the following process.
 - a) Time for entry of passengers on the ground floor.
 - b) Time for exit of the passengers on each floor of discharge.
 - c) Door operation time (opening and closing) and car start time on each floor the lift stops, including ground floor.
 - d) Acceleration and deceleration periods;
 - e) Stopping and levelling periods;
 - f) Periods of full rated speeds between stops going up and
 - g) Periods of full rated speeds between stops going down.
- B) The average interval shall be calculated by the following formula :

$$\text{Interval } I = \frac{T}{N}$$

6.3.4 Location and Arrangement of lifts

The lifts shall be easily accessible from all entrances to the building. For maximum efficiency, they shall be grouped near the centre of the building. Walking distance from the lift to the farthest office or suite shall not exceed 60m.

Arrangement of Lifts

- a) When more than one lifts are installed in a group, they shall be arranged side by side or in two rows facing each other. Separation of lifts in the group shall be avoided.
- b) The lobby in front of lifts shall be wide enough to allow sufficient space for waiting passengers and proper vision of hall button and hall lanterns. Fig 1 to Fig-5 give acceptable arrangement of lifts in a group with acceptable space for waiting passengers. More space shall be allowed in front of the lifts in the main floor than in the upper floors.

6.3.5 Location of Machine Room

The machine room shall, as far as practicable, be placed immediately above the lift well.

If a machine room on the lift well is impracticable for architectural or other reasons, the machine room may be placed below the lift well or in the basement, keeping adequate safety provisions. If the lift machine room is located in the basement, it shall be separated from the lift well by a separation wall.

High speed lifts with gearless machine shall, in all case, have machine room above the lift well.

Machine room shall not be located adjacent to or above sleeping rooms (bed rooms) in residential and hotel buildings; and patients rooms, intensive care rooms and operation theatres of hospital/health care buildings.

6.3.6 Control System

The control of operation of the lift system, levelling, door opening and closing, response to hall calls etc. shall be fully automatic. All control equipment shall be efficient and fail-safe.

control system shall be capable of accelerating the car smoothly to full running speed and stopping the lift with smooth retardation.

Variation in speed of the lift between no load and full load conditions shall not be more than plus or minus five per cent. The control system shall be capable of correcting any tendency to overspeed or underspeed. The control system shall have safety device(s) to stop the lift car if its running speed exceeds its rated speed by ten per cent.

It shall have facility to level or, relevel the lift car within plus or minus 13mm. The levelling system shall be fully automatic and shall correct for over travel or under travel and rope stretch. The car stopping and levelling system shall be unaffected by external influences like variation in load, temperature, rope elongation etc.

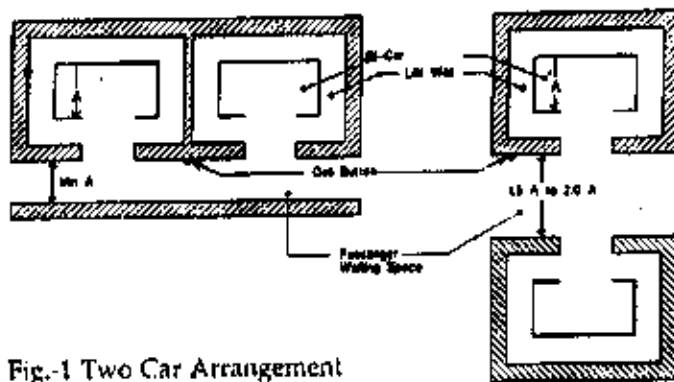


Fig-1 Two Car Arrangement

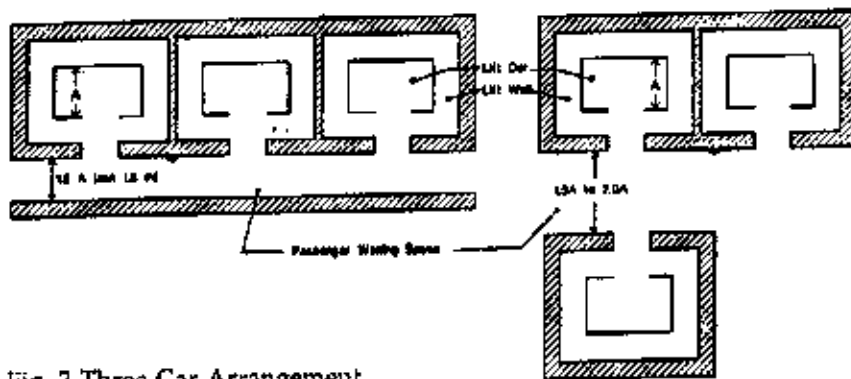


Fig-2 Three Car Arrangement

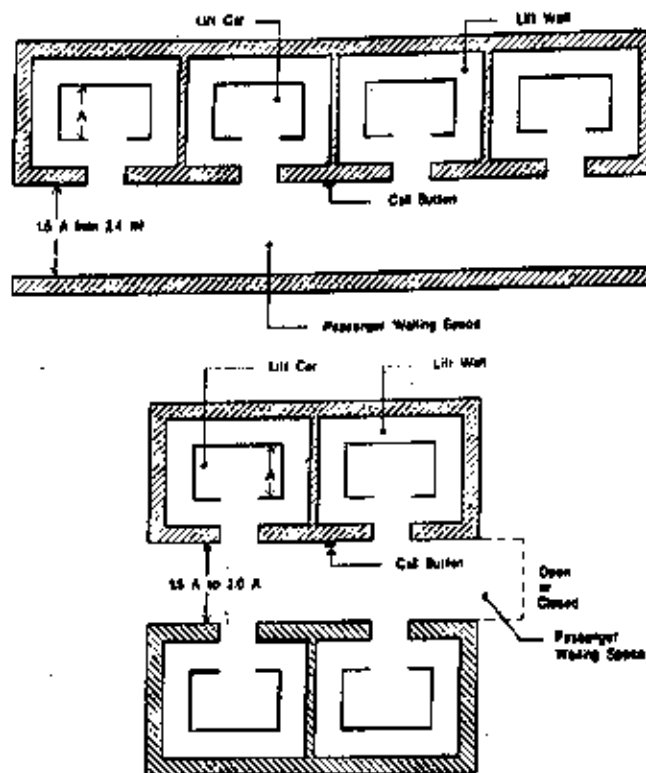


Fig-3 Four Car Arrangement

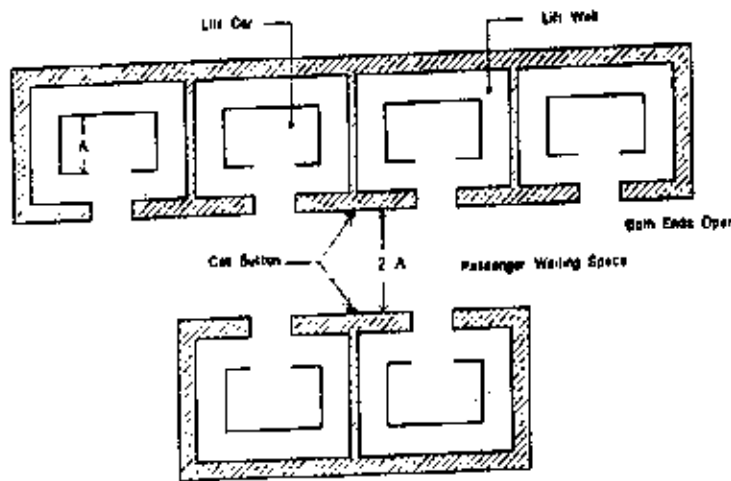
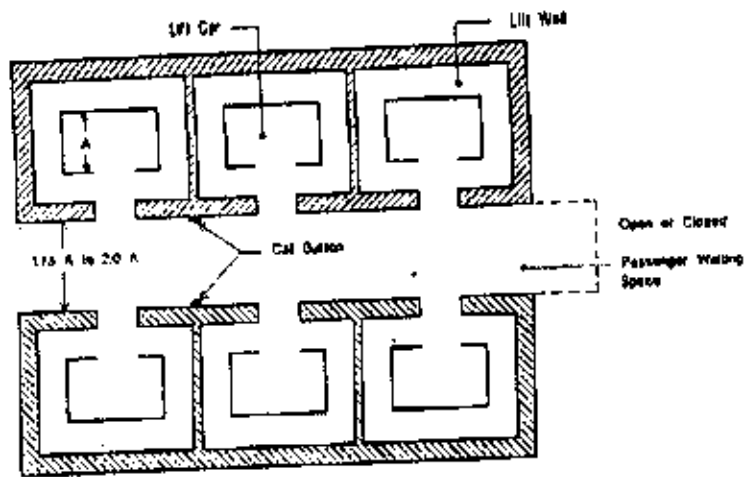


Fig.-4 Six Car Arrangement

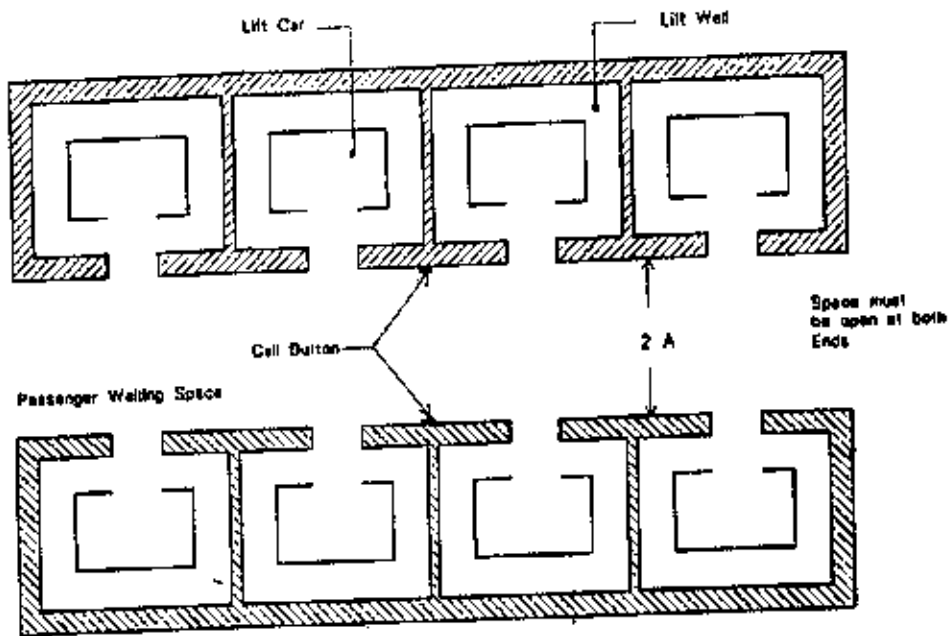


Fig.-5 Eight Car Arrangement

Closing and opening of car doors and landing doors shall be fully automatic and shall operate in full synchronization with one another. Door opening and closing operations shall be so controlled as to ensure proper safety of passengers.

Door opening and closing time and door hold open time shall be automatically controlled to get minimum transfer time in any landing. For larger installations, transfer times shall be independently adjustable to suit the requirements of the building as well as the characteristics of the traffic.

Independent door closing push button shall be provided in the lift car to allow instant door closing. Similarly door opening push button shall be provided in the lift car to reverse the closing motion of the doors or hold them open.

When there are conditions that particularly affect the safety of passengers, the closing of doors shall only be effected by the continuous pressure of push buttons in the lift car or landings.

Each lift shall have key operated switch to transfer from normal passenger control to a car preference control. During car preference control the operation of the lift shall be from the car only and the doors shall remain open until a car call is registered for a floor designation. All landing calls shall be bypassed and car position indicators on the landings for this lift shall not be illuminated.

Provisions shall be made in the control system to take any car out of service still maintaining the controlled operation of the remaining cars of a group of cars required for passenger traffic. It is essential that such provision shall not stop the fireman's control from being operative in the event of the lift being designated as a fireman's lift.

6.4 INSPECTION AND CERTIFICATION

All new lifts, after installation, shall be inspected and tested by the Authority before these are put into normal services.

These shall not be brought into use unless the Authority is satisfied that installations have been carried out as per provisions of this book and test indicate that all the safety devices operate satisfactorily. It shall be unlawful to operate any lift, without a current certificate of inspection issued by the Authority. Certificates shall not be issued when the conveyance is posted as unsafe.

6.4.2 All electrical lines, control lines and earthings of lift, system shall be tested to determine whether these have been installed properly to meet the requirements of the machine.

6.4.3 Testing

Test shall be carried out to determine the operational and safety conditions of lifts, in accordance with the provisions of section below :

Lift : Tests shall be conducted to ascertain that

- a) the motor, brake control equipment and car levelling mechanism function properly.
- b) the door operation is proper and door locking devices function properly.
- c) the car raises and lowers rated load.
- d) the car achieves at least the rated speed.
- e) the lift motor can be overloaded upto a minimum of 10% above the rated capacity.
- f) the safety gear stops the car with the rated load in case of over speed and/or over travel etc.
- g) the buffers function properly, and
- h) the safety gear operate and keeps operation of the lift suspended in case of the lift car is loaded above its maximum capacity.

6.5 OPERATION AND MAINTENANCE

6.5.1 Operation

The owner shall be responsible for the safe operation and maintenance of each lift installation and shall cause periodic inspections, tests and maintenance to be made on such conveyances as required in this section.

The lift, shall receive regular cleaning and lubrication of relevant parts and adequate servicing by authorised competent persons at such intervals as the type of equipment and frequency of service demand. In order that the lift installation is maintained at all times in a safe condition, a proper maintenance schedule shall be drawn up in consultation with the machine manufacturer which shall be strictly followed.

In case of lift, periodic examination of wire ropes, components of landing and car doors, door interlocking mechanism, brakes, gear guides, rollers, channels etc. shall be carried out as recommended by the manufacturer. In no case shall the interval between such inspections exceed six months.

Grooves of drums, sheaves and pulleys of lifts shall also be examined when rope replacement is made. If necessary, the drums, sheaves or pulleys shall be properly remachined.

6.5.2 Sundry Precautions

Adequate precaution shall be taken to guard against any possibility of a lift being operated by unauthorized persons. Precautions shall also be taken to prevent a lift from being operated by any person when it is not intended for use.

No person shall remain in the pit while the lift is working. Adequate precautions shall be taken to protect persons working in the pit from accidental contact with the counter weight.

While the lift is under examination or repairs, suitable steps shall be taken to ensure that the lifts is not operated inadvertently by any person in such a manner as may endanger the safety of persons working in the lift.

No such explosive or other inflammable material shall be carried in the lift car as may endanger the safety of persons and property.

6.5.3 Installation take over/Hand over check points

Electrical Check

- a) Motor Terminals, for tightness.
- b) Control Panel incoming power line, for tightness.
- c) Main Power DB, incoming outgoing connections.
- d) Neatness in cable routing
- e) Neatness in terminations.
- f) Grounding
- g) Insulation Test.
- h) Motor nameplate data and compare with specification.

i) ONE LIFT WITHOUT CAR START MOTOR AND CHECK (AT LEAST ONE HOUR)

- a) Sound
- b) Smell
- c) Motor/Bearing Temperature
- d) Motor Cooling System

ii) ONE LIFT WITH CAR (WITHOUT LOAD) (AT LEAST ONE HOUR)

- Check Manual Operation
- Check Pulley Alignment (Visual)
- Check Rope Tightness
- Make random check for up-down for various floors (at least 1 hr)
- Check sound/smell/motor/bearing temperature in the machine room
- Check for level at landing floors (From Car)
- Check door closing for sound and tightness

- Check for jerking at stop and start (From Car)
- Check internal light/ventilation
- Check controls specified (Make a list of controls specified and check each and every item)
- Check Emergency Power Failure System

iii) **ONE LIFT WITH FULL LOAD (MAY BE DUMMY)**

- Repeat all the checks under item (ii) above.
- Check overload limit and warning system
- Measure speed against specification

iv) **GROUP WITH CAR (WITHOUT LOAD)**

Prepare Check List based on points under (ii) above with one list for each car and note the findings.

v) **GROUP WITH SPECIFIED LOAD (DUMMY OR ACTUAL)**

Prepare Check List based on points under (iii) above with one list for each car and note the findings and compare with specification.

6.5.4. MAINTENANCE WITH DETAIL WORK SCHEDULE

General

- Follow Manufacturer's Maintenance Manual meticulously
- Maintain Log-Book for machine/controller which would be checked and signed by Maintenance Engineer preferably daily but not later than a week.
- Do not allow Departmental Electrician to play with Control Panel, unless the Electrician is fully trained by Manufacturer's trained personnel.
- Since now-a-days PLC (Programmable Logic Controller) is widely used, it is advised to contact the Manufacturer's representative for any maintenance/rectification work.
- The major problem arises from poor-maintenance of the control room. The room must be kept dust-free. Air-conditioning is not essential in lift room if roof is insulated and proper filtered air circulation is maintained in the lift room.

Table - 5
Maximum Inside Net Platform Area for Various Loads

Rated Load (Mass) (Kg)	Maximum Available (Car Area See note) (m ²)	Maximum Number of passengers	Rated Load (Mass) (Kg)	Maximum Available Car Area (m ²)	Maximum Number of passengers
100	0.40	1	975	2.35	14
180	0.50	2	1000	2.40	14
225	0.70	3	1050	2.50	15
300	0.90	4	1125	2.65	16
375	1.10	5	1200	2.80	17
400	1.17	5	1250	2.90	18
450	1.30	6	1275	2.95	18
525	1.45	7	1350	3.10	19
600	1.60	8	1425	3.25	20
630	1.66	9	1500	3.40	22
675	1.75	10	1600	3.56	23
750	1.90	11	1800	3.88	26
800	2.00	11	2100	4.36	30
825	2.05	12	2500	5.00	36
900	2.20	13	-	-	-

Beyond 2500 Kg. and 0.16m² for each 100 Kg. extra

Note : Maximum available car area = (WxD) + Available area near the car door(a) inside the car.

Where: W = Car inside width, m

D = Car inside depth, m

DETAILED WORK-SCHEDULE FOR ANNUAL MAINTENANCE, SERVICING

Daily (before starting of the lift)

- Checking of exact voltage available in the panel.
- Checking of correct phase sequence (i.e. ensuring whether R.S.T, phases are in order or not).
- Checking if landing doors of all floors are closed or not.
- Checking if main hoisting rope is in correct position or not
- Checking if the brake system and deflection pully is in order/working condition or not.
- Cleaning of inside of the lift-cabin (including floor and ceiling) with duster.

WEEKLY

In case of automatic doors (both landing and cabin doors)

- Checking of pick-up strip including minor repairing as and when required.
- Checking of Landing Door Roller including setting in position as and when required.
- Checking of landing Door weight including setting in position as and when required.
- Checking of landing Door Contact including setting in position as and when required.
- Checking of security of (Photo-cell) System including setting in position as and when required.
- Checking of Automatic time Limit System including setting in position as and when required.
- Checking of fuses in the Panel Board including replacing it with a new one as and when required.

- Checking of Emergency Alarm System if any including replacing it with a new one as and when required.

- Cleaning of lift-cabin with soap solution/savlon.

IN CASE OF MANUAL (Collapsible) DOOR

- Checking of Locking Contact including minor repairing as and when required.
- Checking of Rivetting including minor repairing as and when required.
- Checking of Rollers (to ensure if it is accident free) including minor repairing as and when required.

INCASE OF MANUAL (SWING) DOOR

- Checking of Hydraulic Door Closure including minor repairing as and when required.
- Checking of Push Plate including minor repairing as and when required.
- Checking of Hand lever including minor repairing as and when required.
- Checking of Electric Contact and Mechanical Bearings including minor repairing as and when required.

FORTNIGHTLY

- Checking of Main Driving Contact Leaf alignment and relays including servicing and repairing as and when required.
- Checking of Gear oil level including servicing and repairing as and when required.
- Checking of the condition of bush and bearing of the Main Shaft including minor repairs as and when required.
- Checking of the bush and bearing of the Main Hoisting motor and Gear-Box including minor repairing as and when required.
- Checking of the whole system of the landing door contact (i.e. wiring, contact points (etc.) including minor repairing as and when required.
- Checking of the position of indicator system (i.e. bulb, push-button etc.) including minor repairing as and when required.

MONTHLY

- Cleaning of Lift-Cabin, Cabin-Doors, Landing-doors, Hall and cabin Indicator & operation pannel, Lift Pit and main guide.
- Cleaning of counter-weight guide.
- Cleaning of Main Guide-Shoe.
- Cleaning of Counter-weight guide shoe.
- Cleaning of Main guide oiling/greasing (as the case may be).
- Checking of Main Hoisting Rope, Nut-bolts, U-Clamps including minor repairing as and when required.
- Checking of speed governor rope, nut-bolts, U-clamps including minor repairing as and when required.
- Checking of complete emergency speed governor, pully, balancing weight, emergency grip system including minor adjust as and when required.
- Checking of Main Hoisting Rope breakage and strands, including minor repairing as and when required.
- Checking of the Safety-Catch switch including minor repairing as and when required.
- Checking of the rope Slack switch, if any including minor repairing as and when required.
- Checking of the overload system, if any including minor repairing as and when required.
- Checking of the limit switch (contact point and limit roller) in/c. minor repairing as and when required.

- Checking of the Retardation switch including minor repairing as and when required.
- Checking of High speed Cut off switch including minor repairing as and when required.
- Checking of shaft magnet including minor repairing as and when necessary.
- Checking of the magnetic/impulse switch, if any including minor repairing as and when necessary.
- Checking of the Levelling switch including minor repairing as and when necessary.
- Checking of the Levelling plate and bar including minor repairing as and when necessary.
- Checking of the Door returning magnet/returning ramp (Cam), if any including minor repairing as and when necessary.
- Checking of landing door locking system including minor repairing as and when necessary.
- Checking of cabin door micro switch including minor repairing as and when necessary.
- Checking of cabin door Alignment including minor repairing as and when necessary.
- Checking of landing door sill including minor repairing as and when necessary.
- Checking of cabin door and landing door slipper including minor repairing as and when necessary.
- Checking of door roller including oiling and greasing including minor repairing as and when necessary.
- Checking of distance between brake drum and brake liner and brake system.
- Cleaning of entire lift shaft and lift pit and the Machine Room.
- Checking and cleaning and resetting of contact finger including minor repairing as and when necessary.
- Checking of time relay including break-action output voltage alignment including minor repairing as and when necessary.
- Checking of Motor protective switch including minor repairing as and when necessary.
- Checking of Brake-rectifier including minor repairing as and when necessary.
- Checking of Door overload switch including minor repairing as and when necessary.
- Checking of all kinds of fuses.
- Checking of Motor bearing oil level.
- Checking of greasing point of the floor selector and upper surface of the drum, if any.
- Ensuring Lubrication of the drive gear.
- Examining driving rope, tape or chain for wear and tension and adjustment of corrector gear (where applicable).
- Testing of Main Motor insulation.
- Checking of Buffer spring and oil buffer tension.

IN CASE OF D.C. MOTOR

Checking, examining minor repairing, if any of commutators, carbon brush, slip-ring of the main Hoisting Motor (D.C. MOTOR)

Testing, feeding of output voltage of Tacho-Generator, slip-ring, Generator, Terminal, Terminal connection, brush spring tension.

QUARTERLY

- Checking of the main guide clips, nut-bolts etc. including minor repairing as and when necessary.
- Checking of the C.W. guide Clips, nut-bolts etc. including minor repairing as and when necessary.

- Checking of landing door fitting nuts etc. including minor repairing as and when necessary.
- Checking of all nut-bolts of the cabin including minor repairing as and when necessary.
- Checking of joints of Main-Guide and counter weight Guides in/c. minor repairing as and when necessary.
- Checking of tension of Main Hoisting Rope including minor repairing as and when necessary.
- Clearing of Main Hoisting Motor with dust blower.

ANNUALY

- Cleaning of the gear oil after performing all kinds of test of the new gear oil such as viscosity test, flash point test, water containity test etc.
- All kinds of motor heating and vernishing.
- Checking and minor repairing of deflection of pully alignment, wire grove including minor repairing as and when necessary.
- Checking and minor repairing, if necessary of Brake Drum to ensure if it is free from oil and grease holder is free from any kind of blockage, spring tension, level, alignment.
- Checking of Brake Drum liner including revetting/pasting etc. including minor repairing as and when required.
- Complete panel board over-hauling and minor repairing, if required.
- Checking of all earthing including minor repairing as and when required.
- Checking of Main Motor and Gear Coupling Rubber Bush including minor repairing as and when required.
- Checking of Alignment of Main Guide, counter-weight Guide, Landing Door and Main Motor and Minor setting as and when required.
- Checking of deflection pully, bearing and oil level including minor repairing as and when required.
- Checking of the trailing cable including minor repairing as and when required.

At the end of every month the Sub-Divisional Engineer-in-charge shall invariably submit a certificate of Maintenance (in two copies) duly signed by the Sub-Assistant Engineer-in-charge.

The Sub-Divisional Engineer-in-charge will frequently check the maintenance work which is done as per schedule above. He (the S.D.E) and the authorised representative of contractor (if engaged on contract basis) will sign on the report. The report will be submitted to the Executive Engineer-in-charge, which shall inturn be submitted by him to the Superintending Engineer concerned.

If any of the items under the maintenance schedule of weekly, Fortnightly, Monthly, Quarterly, Annually is omitted due to some reason in due time, this has to be completed within the next three (3) days time, which after completion has to be reported in writing to the concerned Executive Engineer.

The contractor (if engaged) should keep his required technical personal for the whole period during which the lifts will be in operation as per contract agreement (if any).

Appendix - A
Format for Particulars of Lifts.

LIFT

- a) Use, Passenger/Goods/Services/Hospital
- b) Number of stops _____
- c) Capacity per lift : Number of Passenger or wt. in kilogram.
- d) Rated Speed : _____ m/s m/s
- e) Travel height : _____ m m
- f) Size and type of Car doors _____
- g) Size and type of landing doors : _____
- h) Size(s) and location(s) of lift well(s) : _____
- i) Number of doors : _____
- j) Method of control(s): _____
- k) Location of machine room : _____
- l) Position of counter weight: _____
- m) Size of car platform : _____
- n) Construction, design and finish of car body work: _____
- o) Construction, design and finish of car platform: _____
- p) Particulars of ventilation of the car : _____
- q) Particulars of control buttons in car : _____
- r) Particulars of position indicators in car : _____
- s) Particulars of call buttons in landing : _____
- t) Particulars of car position indicators in landings : _____
- u) Electric supply : _____
 Power: _____ Volts, ac/dc _____ phase _____ Hz/wire system _____
 Lighting : _____ Volts, ac/dc _____ Hz _____
- v) Additional requirements, if any :

ESCALATOR

- a) Number of escalators required : _____
- b) Capacity of each escalator (No. of people/hr): _____
- c) Rated speed _____ m/s
- d) Travel height _____ m, Treavel length _____ m
- e) Width of escalator _____ m
- f) Construction, design and finish of balustrade : _____
- g) Details of steps : _____
- h) Materials of landing plate : _____
- i) Electric supply
 Power _____ Volts ac/dc _____ phase
 _____ Hz/Wire system
- j) Additional requirements, if any : _____

AIR CONDITIONING

7.1 Heat Transfer :

When two systems originally at different temperatures are brought into contact such that the mass flow across the boundary does not take place, but energy transfer can take place, it is shown by common experience that these two systems come to the equilibrium and reach a temperature common to both and that temperature is in between the two original temperatures of the systems. Thus the systems have influenced each other. This influence has passed from system at higher temperature to system at lower temperature, or we say that heat transferred from system at higher temperature to system at lower temperature by virtue of temperature difference. It is the energy in transition and is not property. Heat will be denoted by Q and its units in metric system are kcal. In SI units it is expressed in Joules abbreviated as J.

Also $1 \text{ kcal} = 4186.8 \text{ J} = 4.1868 \text{ kJ}$

$1 \text{ kJ} = 0.2388 \text{ kcal}$.

Heat flow rate is expressed as kcal/hr in MKS units and Watts or J/sec in SI units. Also,

$1 \text{ kcal/hr} = 1.163 \text{ J/sec} = 1.163 \text{ watt. (watt sec.)}$

$1 \text{ watt} = 0.86 \text{ kcal/hr.}$

7.2 Pure Substance - Thermodynamic State : In general a pure substance exists in the following three forms :

- (i) Solid phase
- (ii) Liquid phase
- (iii) Vapour or gaseous phase

Under certain conditions, all these three phases may co-exist. The co-existence of two phases is very common. Water is taken as an illustrative pure substance. When ice melts there is an transformation of phase from solid to liquid. This is called melting or fusion of ice. Transformation can take place in the opposite direction i.e. from liquid to solid. This is called freezing or solidification. Similarly the transformation from the liquid phase to vapour phase is called vaporization. The transformation in the opposite direction i.e. from vapour to liquid is called condensation.

7.3 Phase Transformation at Constant Pressure: Refer Fig. A Let the cylinder Fig A(a) contains 1 kg of ice under a pressure $p \text{ kgf/cm}^2$ exerted by a weight W placed on the free frictionless piston. Let us assume that $p_1 = 5 \text{ kgf/cm}^2$ and the ice is at a temperature of -10°C . Then let heat be added continuously. First the ice gets warmer and its temperature rises as recorded by thermometer till the temperature little lower than 0°C is reached. The freezing temperature of water decrease

slightly with pressure, being 0°C at standard atmospheric pressure. The warming up process is shown by AB in Fig. B. After this the ice begins to melt and a two phase mixture of ice and water remains at the same temperature. No rise in temperature is recorded while heat is being added. This is shown by BC in Fig. B. At point C, all the ice has melted and we have only one phase i.e. liquid water under the same pressure of 5 kgf/cm^2 as shown in Fig.A(b). The quantity of heat required to transform ice into water while there is no change of temperature is called heat of fusion. The freezing point as experimentally found out is a function of pressure, decreasing with an increase in pressure. If heat is further added to water, its temperature starts rising again and continues to do so till the water reaches the temperature of vaporization or boiling. This process is represented in Fig.B. by line CD. The boiling temperature is again a function of pressure, its value being 100°C at standard atmospheric pressure. At 5 kgf/cm^2 it boils at 151.84°C . This temperature is called the saturation temperature for the stated pressure. It can also be said that at 151.84°C , the saturation pressure of water is 5 kgf/cm^2 . After water has reached the saturation temperature, it starts vaporising while temperature remains same and once again we get a two- phase mixture of water and water vapour as shown in Fig.A(c). The two-phase system cannot be defined only by its pressure and temperature. Pressure and temperature are not independent variables. If pressure is known, the corresponding temperature of the two-phase system is known. Thus the state of vapour is defined by either the pressure or temperature and the quality x , i.e. the fraction of vapour in the whole mass. The quality is the percentage of mass that is vapour. This process of vaporization is represented by line DE. At point E, all the water has vaporised and saturated vapour at pressure $p=5 \text{ gf/cm}^2$ is obtained as shown in Fig.A(d). And the heat required to vaporise the liquid to vapour at constant temperature is known as the latent heat of vaporization.

On further heating, i.e. heating after the quality of the vapour is 100% a further rise in temperature is recorded by the temperature thermometer and the volume will also increase as shown in Fig. A(e). The vapour is said to be superheated. Therefore, superheated vapour is vapour at any temperature above the saturation temperature.

7.4 REFRIGERATION SYSTEM (SIMPLE VAPOUR COMPRESSION)

CONCEPT DEVELOPMENT

All Vapour compression refrigeration systems are designed and built around these basic thermodynamic principles :

1. Fluids absorb heat while changing from a liquid phase to vapour phase and reject heat in changing from a vapour phase to a liquid phase.
2. The temp at which a change in phase occurs is constant during the change, but this temp will vary with the pressure.

At one fixed pressure vaporisation takes place only at fixed corresponding temp. However, the temperatures of vaporisation at a particular pressure, are different for different fluids.

3. Heat will flow from body at higher temperature to a body at lower temperature.
4. In selecting metallic parts of cooling and condensing units, metals are selected which have a high heat conductivity.
5. Heat energy and other forms of energy are mutually convertible with directional relationship imposed by the second law of thermodynamics.

7.5 DESIGN ASPECT OF AIR-CONDITIONING SYSTEM

- 7.5.1 Select internal conditions required, temperature and humidity, whether for comfort or for process or for equipment/storage area.
- 7.5.2 Calculate cooling load required, floorwise/zonewise based on Design-criteria given in ASHRAE Hand Book/Carrier's Hand Book/Trane's Hand Book. Design Parameters like natural heat gain, occupancy, room orientation, smoking/no smoking zones and corridor space should be taken into account. Add ventilation load to the cooling load. Consider use of Air-Curtains at certain areas to reduce load requirement.

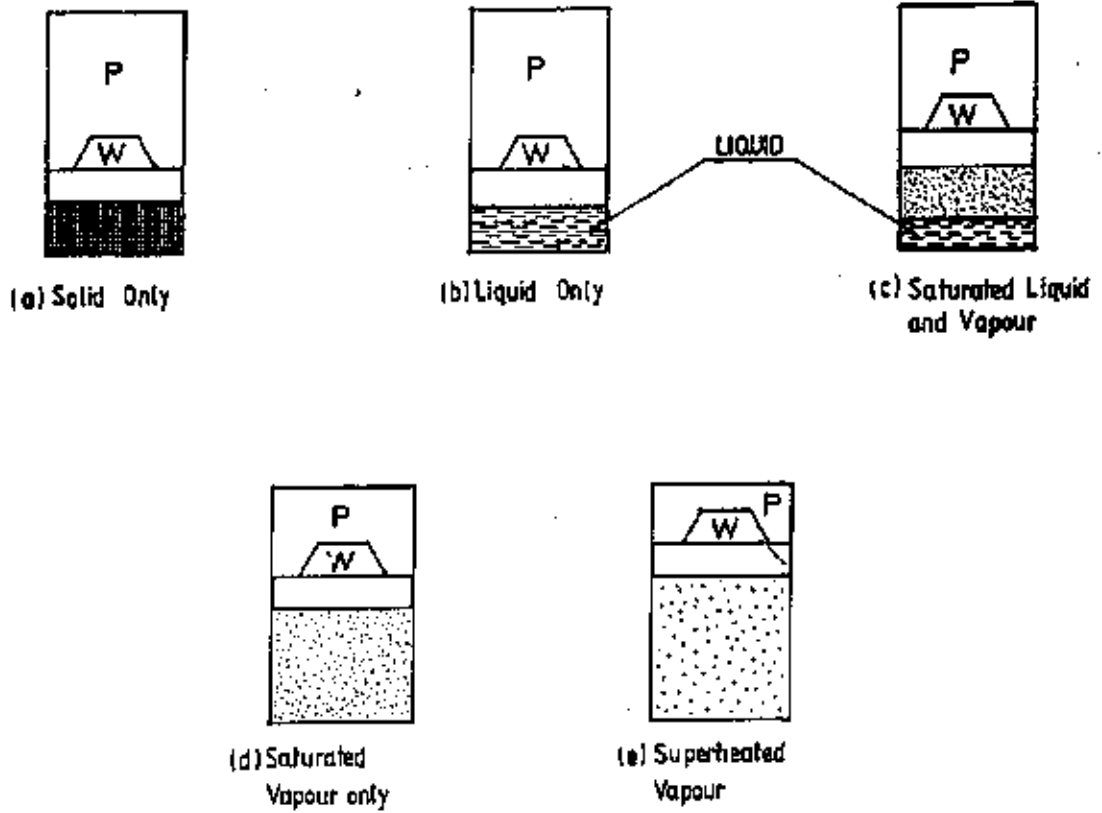


Fig.-A

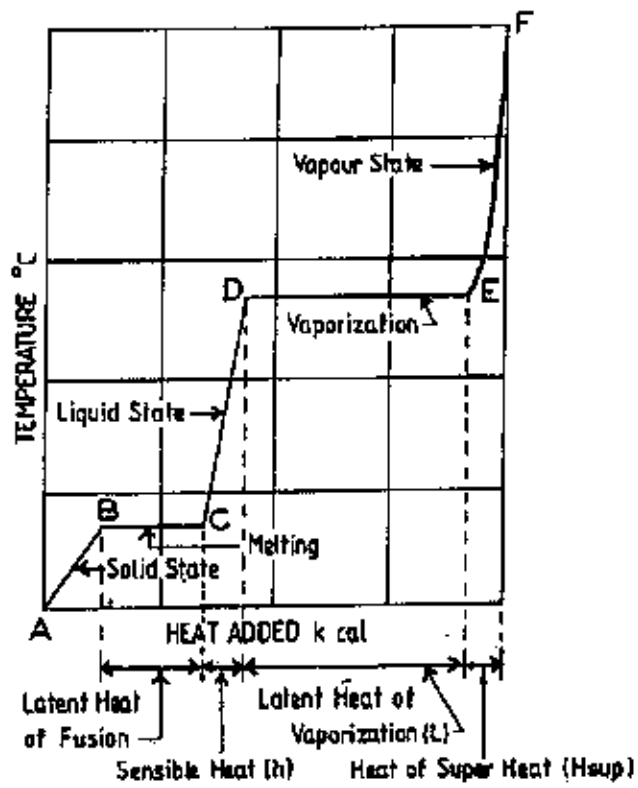
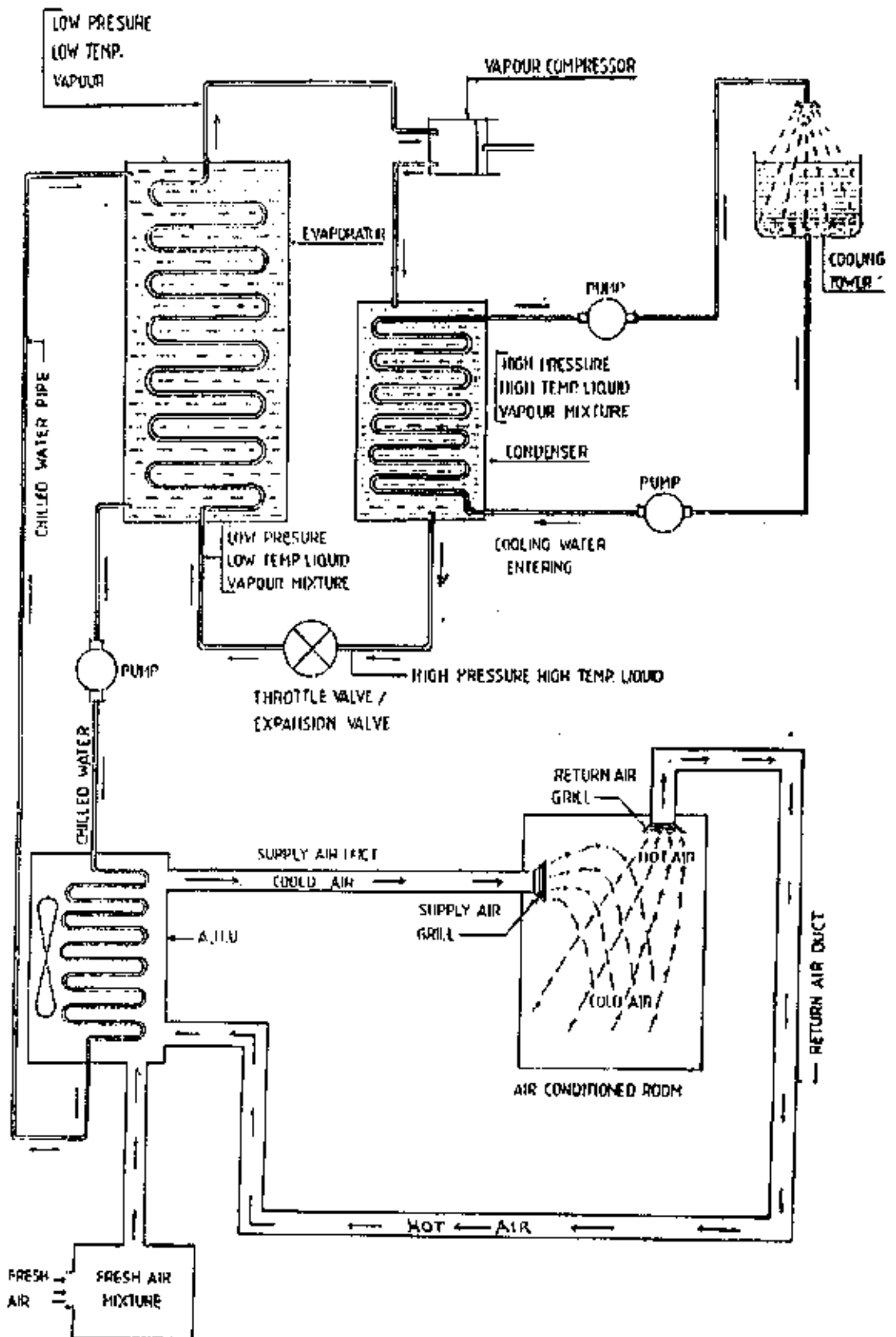


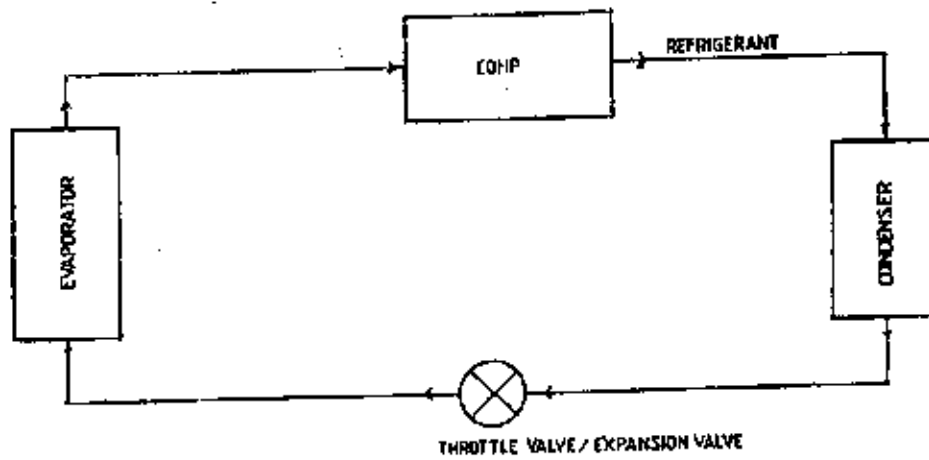
Fig.-B



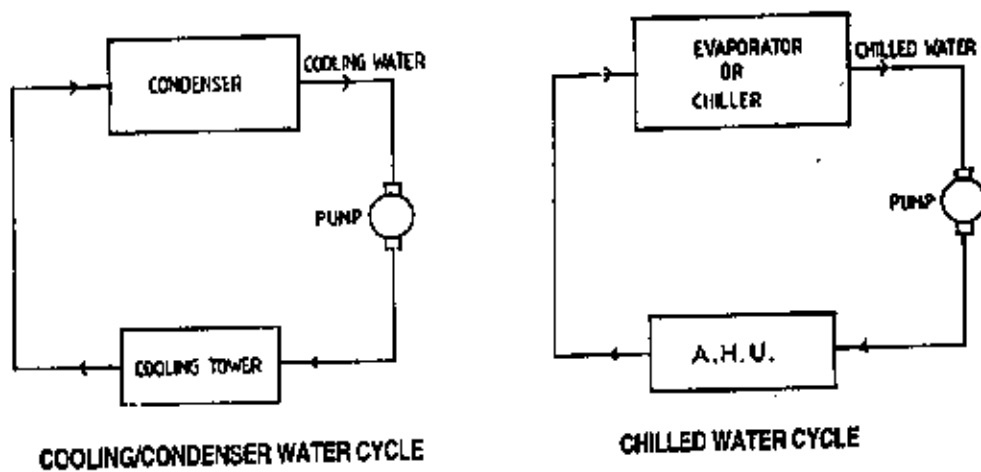
SCHMATIC DIAGRAM OF COMPONENTS OF CENTRAL A. C. SYSTEM

Fig.-C

DIFFERENT CYCLES OF PERFORMANCE IN A CENTRAL AIR CONDITIONING SYSTEM

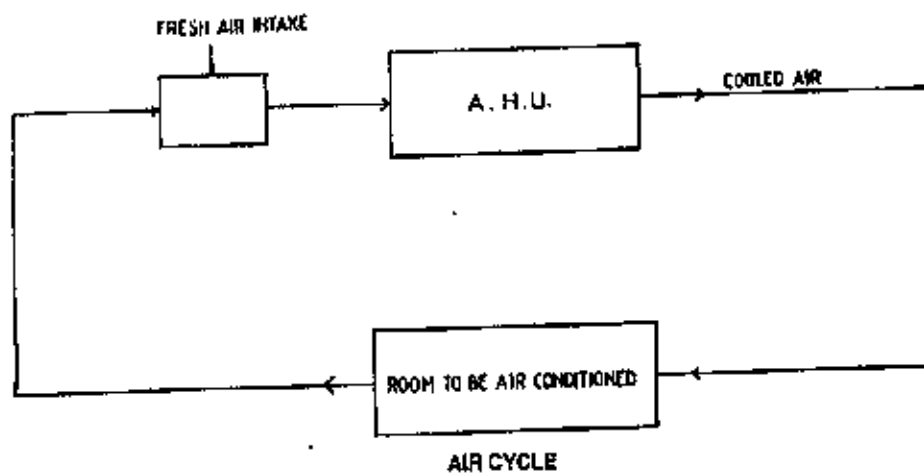


REFRIGERANT CYCLE



COOLING/CONDENSER WATER CYCLE

CHILLED WATER CYCLE



AIR CYCLE

Fig.-D

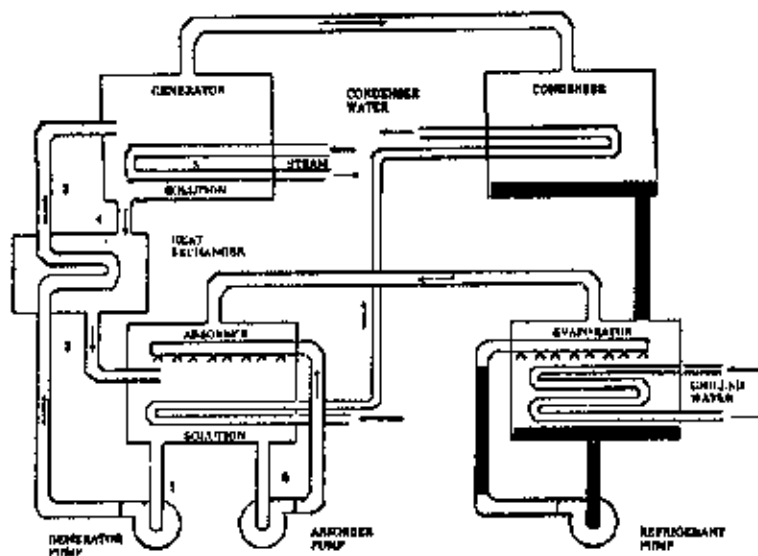


Fig.-E Absorption Refrigerant Cycle

- 7.5.3 Select the system of Air-conditioning depending on the type of Building and its use. By system, we mean All-Air, All-water and Air/water mixed.
- 7.5.4 Once the system is selected, the duct/pipe layout must be carefully designed to have required airflow/water flow in conditioned area and return air/water system. Short circuiting between supply air outlets and return air outlets should be avoided.
- 7.5.5 While designing Air-conditioning system in Bangladesh, the comfort temperature/humidity for people, the dust and moisture content of local air must be get in mind. Also fresh air-requirement of the local occupants must seriously be taken into account. Since higher fresh air requirement increases the cost of the system, a compromise should be done with the inside temperature/humidity to maintain fresh air requirement. Lesser the fresh air, greater is the chance of fungus growth in the air-conditioned area from which persons working in the air conditioned area are attacked with Fungus Allergy. Once the cooling load is determined, equipment selection made, the next important point to be considered is the machine room layout. It is a hard task to extract enough space from the building for a comfortable layout of the plant-Room equipment. No compromise should be made on space requirement which is very vital for equipment operation maintenance.
- 7.5.6 In Air-conditioning system be it in the plant Room or in the conditioned area sound level should be kept at as minimum as possible - specially for the office areas.
- 7.5.7 Sepcial consideration is to be given to Heat Shock i.e. movement from cold area to normal area (in the summer season specially) would cause the persons to catch cold and therefore, the temperature between Air-conditioned area, corridor and outside condition to be carefully considered for health reason.
- 7.5.8 In designing Air-nditioning System for this country, one must remember that we live in a natural moderate temperature excepting for a short period of high temperature. So what is comfort to a person in cold countries or very hot countries, is not applicable to Bangladeshies. Room temperature should be so selected that a local person can use the room without coat and tie. Should certain areas/rooms are to be so maintained that use of coat and tie is a must those areas should be designed specially and that would keep the cost of the system own.
- 7.5.9 In order to have a long life of the Central plants, due consideration should be given to water-treatment, in case of water cooled chillers.

Living in Air-conditioned area is hazardous if enough fresh-air is not introduced. In residence, where rooms are full of pot plants, fresh air requirement is to be increased. In room air cooler, the fresh air inlet should always be kept open.

7.5.10 The split-aircoolers do not have any provision for fresh air-inlet and the rooms polluted air full of carbon-dioxide and human odour is being circulated. In case use of split-aircoolers is a must, extra arrangement must be made to introduce fresh air of adequate quantity.

7.6 INSIDE DESIGN CONDITIONS

7.6.1 For comfort air-conditioning the inside design conditions shall be selected with an objective to reduce energy consumption in the operation of the air-conditioning system. Acceptable values of inside design conditions for summer is provided in Table-A. Unless otherwise specially required the design calculations shall be based on the normal practice values of Table - A.

7.6.2 To avoid thermal shock the difference between the dry bulb temperature of outdoor air and indoor air shall not exceed 11°C. If it is absolutely necessary to have a difference more than 11°C there shall have adequate provision for ante-room to reduce the effect of thermal shock.

7.6.3 Velocity of air in an air-conditioned space in the zone between the floor level and the 1.5m level shall be within 0.12m/s and 0.25m/s for comfort applications for commercial buildings and for other applications it shall not exceed 0.5 m/s.

7.7 OUTSIDE DESIGN CONDITIONS

7.7.1 The outside design conditions for summer months for different cities are provided in Table - B. Selection of outside design conditions from this table shall be based on requirements of the application and the per cent of time the outside air temperature is allowed to exceed the outside design conditions.

7.7.2 In case of stringent design conditions a meteorologist with experience in applied climatology may be consulted to evaluate conditions such as the formation of heat sinks in urban areas the duration of extreme temperatures project sites located remotely from reporting stations.

7.8 VENTILATION AIR

7.8.1 Every space served by the air-conditioning system shall be provided with outside fresh air not less than the minimum amount mentioned in Table - C. If adequate temperature regulation along with efficient filtration of air and absorption of odour and gas are provided the amount of fresh air requirement may be reduced. However in no case the outdoor air quantity shall below than 2.5 l/s per person.

7.8.2 In hospital operation theaters all outdoor air supply is recommended to overcome explosion hazard of anesthetics and to maintain sterile condition. However if adequate filtration with efficient absorption of anesthetics and laminar flow of supply air is provided the outside air requirement may be substantially reduced.

7.9 NOISE AND VIBRATION

7.9.1 Air-conditioning heating and ventilation system design and installations shall consider all the aspects of noise and vibration control related to the system.

7.9.2 Vibration Control: Appropriately designed vibration isolators shall be installed under the machinery to restrict vibration transmission to structures. Similarly vibration isolators shall also be used between a machinery and all pipe work and duct work including the supports when applicable.

7.10 FIRE DAMPER

Fire dampers shall be provided at locations where air distribution systems penetrate assemblies that are required to be fire resistance rated by Bangladesh National Bldg. code.

Table - A
Inside Design Conditions for Summer

Type of Application	Normal practice			Special practice	
	Dry Bulb °C	Relative Humidity %	Temp Swing °C	Dry Bulb °C	Relative Humidity %
GENERAL COMFORT Apartment, House, Hotel Office, Hospital, School etc.	24.5-26	55-50	1-2	23.5-24.5	50
RETAIL SHOPS (Short term occupancy) Department Store, Bank, Supermarket etc.	24.5-26	60-50	1-2	24-25.5	50
LOW SENSIBLE HEAT FACTOR APPLICATIONS Auditorium, Places of worship, Bar, Restaurant, Kitchen etc.	25.5-26.5	60-50	0.5-1	24.5-25.5	60-50
FACTORY COMFORT Assembly areas, Machining rooms etc.	25.5-26.5	60-50	1-2	25-26.5	55-50

TABLE - B
Outside design Conditions for Major Cities

Column-1 Name of City	Column-2 Design Dry Bulb and Mean Coincident Wet Bulb Temperature °C						Column-3 Mean Daily Range °C	Column-4 Design wet Bulb Temperatures °C		
	1%		2.5%		5%			1%	2.5%	5%
	Dry bulb temp	Wet bulb temp	Dry bulb temp	Wet bulb temp	Dry bulb temp	Wet bulb temp				
Dhaka	36	27.5	35	27.5	34	28	7.5	29.5	29	26.5
Chittagong	33.5	27.5	33	27.5	32.5	27.5	7.0	28.5	28	27.5
Khulna	36.5	29	35.5	29	34.5	29	8.0	30	29.5	29
Rajshahi	39.5	24	38	24.5	36	25	9.5	29.5	29	29

TABLE - C
Outdoor Air Requirements

Occupancy Classification	Outdoor Air Quantity(l/s) per Person Unless Otherwise Indicated)	
	Recommended	Minimum
Assembly		
Food services		
Bars and cocktail lounges	17.5-20	15
Cafeterias fast food centres	17.5	15
Dining rooms	7.5-10	5
Kitchens	17.5	15
Museums		
Exhibit halls	5-7.5	3.5
Warehouses	3.5-5	2.5
Workrooms	7.5-10	5
Public (meeting) facilities		
Assembly rooms	10-12.5	7.5
Ballrooms	10-12.5	7.5
Conferenece rooms	12.5-15	10
Lobbies	5-7.5	3.5
Theaters		
Auditoriums(no smoking)	2.5-5	2.5
Lobbies, foyers and lounges	12.5-15	10
Projection booths *	-	5
Stages TV and movie studios	6-7.5	5
Ticket booths	3.5-5	2.5
Offices		
Computer rooms	3.5-5	2.5
Conference rooms	15-20	12.5
Duplicating and printing rooms	5-7.5	3.5
Office space	7.5-12.5	7.5
Waiting rooms	7.5-10	5
Darkrooms	7.5-10	5
Research institutes		
Laboratories	10-12.5	7.5
Laboratories, radioisotope, chemically and biologically toxic. *	10-12.5	10
Educational		
Schools		
Auditoriums	2.5-3.8	2.5
Classrooms	5-7.5	5
Classrooms	12.5-15	10
Gymnasiums	5-7.5	5
Laboratories	5-6	3.5
Libraries		
Lunchrooms, dining halls, common rooms lounges	7.5-10	5
Music rooms, rehearsal rooms	7.5-10	5
Training shops	5-7.5	5
Corridors	10-12.5	7.5
Hospitals, nursing and convalescent homes		
Autopsy rooms.*	20-25	15
Delivery rooms, trauma rooms	-	10
Laboratories	10-12.5	7.5

	Operating rooms	-	10
	Patient rooms	7.5-10	5
	Pharmacy, medication rooms	10-12.5	7.5
	Physical therapy areas and treatment rooms	10-12.5	7.5
	Recovery and intensive care rooms	-	7.5
Residential	Dwelling units		
	General living area, bedrooms, all other rooms	3.5-5	2.5
	Kitchens, baths, toilets.***	15-25	10
Special areas	Elevators	-	5
	Exits and corridors**	-	0.1
	Lockers and dressing rooms	-	15
	Nonpublic bathrooms	15-25	10
	Public bathrooms	10-12.5	7.5

- Note : * Return air shall be exhausted
 ** Outdoor air quantity per m² of floor area
 *** Installed capacity for intermittent use.

7.11 EQUIPMENT INSTALLATION

7.11.1 **General :** Mechanical equipment and appliances shall be installed in accordance with the manufacturer's installation instructions for the labelled equipment.

Identification of Equipment : When more than one air-conditioning, heating, refrigerating or ventilation systems are installed on the roof of a building or within the building each equipment shall be identified as to the area or space served by the equipment.

Access : All mechanical equipment and appliances shall be accessible for inspection, service, repair and replacement without removing permanent construction. Unless otherwise specified not less than 750mm of working space and platform shall be provided to service the equipment or appliance.

Appliance controls gauges, filters, blowers, motors and burners shall be accessible. The operating instructions shall be clearly displayed near the appliance where they can be read easily.

7.11.2 Location

Remote Location: Where an appliance is located in a remote location a walkway having a minimum width of 600mm shall be provided leading from the access opening to the appliance.

Hazardous Location : Appliances installed in garages, warehouses or other areas where they may be subject to mechanical damage shall be installed behind suitable protective barriers or at a suitable height above the floor or located out of the normal path of vehicles to guard against such damages.

Outdoor Installation : Mechanical equipment and appliance located outdoors shall be approved for outdoor installation. All outdoor installed equipment shall be so located that the sound level shall not be more than 65 dB when measured anywhere on the property boundary line.

7.11.3 Electrical Installations

Equipment regulated by this code requiring electrical connections of more than 50 volts shall have a positive means of disconnect adjacent to and in sight from the equipment served. A 230volt AC grounding type receptacle shall be located within 8m of the equipment for service and maintenance purposes. The receptacle need not be located on the same level as the equipment. Low voltage wiring of 50volts or less within a structure shall be installed in a manner to prevent physical damage.

Permanent lighting shall be provided to illuminate the area in which an appliance is located. For remote locations the light switch shall be located near the access opening leading to the appliance.

Exceptions:

Lighting fixtures need not be installed when the fixed lighting for the building will provide sufficient light for safe servicing of the equipment.

Condensate Wastes : Condensates from air cooling coils fuel burning condensing appliances and the overflow from evaporative coolers and similar water supplied equipment shall be collected and discharged to an approved plumbing fixture and disposal area. The waste pipe shall have a slope of not less than 1 in 100 and shall be of approved corrosion resistant material and approved size. Condensate or waste water shall not drain over a public way.

Personnel Protection : A suitable and substantial metal guard shall be provided around exposed flywheels, fans, pulleys, belts and moving machinery which are portions of air-conditioning heating and ventilation system.

7.11.4 Return Air and Outside Air

- a) **Source :** A cooling unit shall be provided with outside air return air or both Cooling system regulated by this code and designed to replace required ventilation shall be arranged to deliver into the conditioned space not less than the amount of outside air specified in this code.
- b) **Prohibited Sources :** The outside air or return air for a cooling system or cooling unit shall not be taken from the following locations:
 - i) Closer than 3m from an appliance vent outlet a vent opening or a plumbing drainage system or the discharge outlet of an exhaust fan unless the outlet is 1m above the outside air inlet.
 - ii) A hazardous or in sanitary location or a refrigeration machinery room.
 - iii) A closet, bathroom, toilet or kitchen.
- c) **Return Air Limitation :** Return air from one dwelling unit shall not be discharged into another dwelling unit through the cooling system.

Air Velocity : Cooling systems shall be designed and constructed so that velocity through filters does not exceed the filter manufacturer's recommendation.

Air Handling Unit: Air handling units shall be installed on vibration isolators to restrict transmission of vibration to the building structure. The base of the air handling unit shall be minimum 75mm above the adjoining floor level. All air handling unit rooms shall have properly installed floor drains.

7.11.5 PACKAGED AIR-CONDITIONERS

Prohibited Use : Packaged air-conditioners shall not be used for

- a) Operation theatres where provisions for 100 per cent fresh air and high quality filtration of air are required.
- b) Special applications like sterile rooms for hospitals and clean rooms where high efficiency filtration is required.
- c) Sound recording studios and other areas where criteria for acoustics are stringent.

Exceptions:

Single package units when installed far away from the air-conditioned space and are provided with properly designed sound attenuators which can maintain the desired sound level inside the conditioned space.

- d) Area requiring close and independent control of temperature and relative humidity.

Exception:

Computer room air-conditioning

7.12 REFRIGERANTS

7.12.1 **Classification :** Refrigerants listed in Table - D and Table - E or other refrigerants equivalent in safety to life, limb, health or property shall only be used in refrigerating equipment.

Group-1 Refrigerants

- i) **Direct Systems :** The maximum amount of Group 1 refrigerants in direct systems shall not exceed that set forth in Table - D.
- ii) **Indirect Systems :** The amount of Group 1 refrigerants used in indirect systems shall be unlimited.
- iii) **General :** Condensing units or combinations of refrigerant interconnected condensing units totalling 75KW or more rating which contain a Group 1 refrigerant shall be enclosed in a refrigeration machinery room.

Group 2 Refrigerants : A mechanical refrigerating system or unit refrigerating system containing a Group 2 refrigerant shall not be located within a building unless all refrigerant containing portions of the system are enclosed in refrigeration machinery room. Such system when installed outside of a building shall be located at least 6m from an exit door window or ventilating air inlet in a building.

Direct refrigeration systems containing Group 2 refrigerants shall not serve an air cooling or air-conditioning system used for human comfort.

7.12.2 **Storage of refrigerants :** Refrigerants not contained in refrigeration system regulated by the Code shall be stored in original containers kept in machinery room. The total amount shall not exceed 135kg.

A portable refrigerant container shall not be connected to the refrigerating system for a period longer than is necessary to charge or discharge the refrigerating system.

7.13 VENTILATION SYSTEMS

Where Required: Every space intended for human occupancy shall be provided with ventilation by natural or mechanical means during the periods when the room or space is occupied.

7.13.1 Natural Ventilation

Natural Ventilation Surces : Natural ventilation of an occupied space shall be through windows, doors louver, skylights or other openings to the outdoor. Such ventilating openings shall open to the sky or a public street space alley, park, highway yard, court, plaza or other approved space which comply with the requirements of the building code.

Area of Ventilating Openings : The minimum ventilating opening to the outdoors shall be four per cent of the floor area being ventilated.

Adjoining Spaces : Where rooms and spaces without opening to the outdoors are ventilated through an adjoining room the unobstructed opening to the adjoining rooms shall be at least eight per cent of the floor area of the interior room or space but not less than 2.33m². The ventilation opening to the outdoors shall be based on the total floor area being ventilated.

TABLE - D
Group 1 Refrigerants

Refrigerant Designation	Name	Maximum Quantity in kg per 100m ³ of Space Intended for Human Occupancy
R-11	Trichlorofluoromethane	56
R-12	Dichlorodifluoromethane	49.6
R-13	Chlorotrifluoromethane	43.2
R-13B1	Bromotrifluoromethane	60.8
R-14	Tetrafluoromethane	36.8
R-21	Dichlorofluoromethane	20.8
R-22	Chlorodifluoromethane	35.2
R-30	Dichloromethane (Methylene chloride)	9.6
R-113	Trichlorotrifluoroethane	38.4
R-114	Dichlorotetrafluoroethane	70.4
R-115	Chloropentafluoroethane	64
R-C318	Octafluorocyclobutane	80
R-500	Dichlorodifluoromethane (73.8%) and Ethylidene Fluoride (26.2%)	41.6
R-502	Chlorodifluoromethane (48.8%) and chloropentafluoroethane (51.2%)	48
R-744	Carbon dioxide	17.6

TABLE - E
Group- 2 Refrigerants

Refrigerant Designation	Name
R-40	Methylchloride
R-611	Methylformate
R-717	Ammonia
R-764	Sulphur dioxide

Openig Below Grade : Openings below grade shall be acceptable for natural ventilation provided the outside horizontal clear space measured perpendicular to the opening is one and one-half times the depth below the average adjoining grade.

7.13.2 Mechanical Ventilation

Where Required : Mechanical ventilation shall be provided in all occupiable rooms spaces where the requirements for natural ventilation are not met in all rooms or spaces which because of the nature of their use or occupancy involve the presence of dust fumes, gases, vapours or other noxious or injurious impurities or substances which create a fire hazard where space temperature is more than 40°C where relative humidity of inside air is more than 70 per cent where job conditions require ventilation or where required as per provisions of this code.

7.13.3 Recirculation

Amount of Recirculation : Not more than 67 per cent of the required ventilation air specified in Table - F shall be permitted for recirculation when the concentration of particulates is less than specified in Table - G. Air in excess of the required ventilation air shall be permitted to be completely recirculated. Air shall not be recirculated to another dwelling unit or occupancy of dissimilar use.

Not more than 85 per cent of the required ventilation air shall be permitted to be recirculation when the system is equipped with effective adsorption or filtering equipment such that the condition of the air supplied to the room or space is within the quality limitations of Table

Prohibited Use of Recirculated Air : Air drawn from mortuary rooms, laboratories or toilets or any space where an objectionable quantity of flammable vapours, dust, fumes or noxious gases is present shall not be recirculated. Air drawn from rooms that must be isolated to prevent the spread of infection shall not be recirculated.

7.14 INSPECTION TESTING AND COMMISSIONING

7.14.1 Inspection

General : All air conditioning, heating and ventilation system shall be inspected and tested by the Authority before the system is commissioned for normal operation. It should be ensured that these are carried out thoroughly and that all data and results are properly documented. It is recommended that whole inspection, testing and commissioning be done under the guidance and control of a single Authority.

Inspection : All machinery equipment and other accessories of the air-conditioning heating and ventilation system shall be inspected by the Authority to determine whether the system components and the system as a whole has been installed as per design and provisions of this code, proper safety requirements have been maintained and adequate fire protection measures have been taken.

Inspection shall also be carried out on structural supports, hangers, fastening devices, vibration isolators etc.

7.14.2 Testing

General : All machinery equipment and other accessories shall be tested as per approved procedures. Tests shall be conducted to determine the strength, capacity of any item and performance of any machine and equipment. All test data shall be properly documented.

Pressure Testing of Piping : All field installed refrigerant and hydrolic piping system along with their valves and pipe fittings shall be tested at their approved test pressures to determine whether the piping system can withstand the test pressures.

Air Distribution System Testing : All ducting system shall be tested to determine whether the duct system has any leakage at test pressures. All air terminals and air dampers shall be tested for their flow characteristics.

Machinery and Equipment : Tests shall be conducted on machinery and equipment to determine whether these operate and function properly. All machinery and equipment also be tested for their electrical power consumption characteristics and overall performance. Before performance testing of the system all air distribution system and hydrolic system shall be properly balanced by approved procedure.

Safety Devices and Controls : Tests shall be carried out to determine whether the safety devices and controls function properly.

All air filters shall be tested in accordance with the latest standard.

7.14.3 Commissioning

If the Authority becomes satisfied regarding satisfactory installation and performance of the air-conditioning, heating and ventilation system after testing the system shall be commissioned following approved procedure. Before complete commissioning all air distribution systems and hydrolic systems shall be properly balanced and all the controls and their sensors shall be properly adjusted.

7.15 INSTALLATION CHECK POINTS

Central Air Conditioning

PLANT ROOM

- i) Check Electrical System for proper terminations, insulation resistance and clean cable layout.
- ii) Start the system as per Manufacturer's instruction of start-up and note all the measurements with no load, with 25% load, with 75% load and with 100% load. Special note is to be taken of unusual sound, vibration, and smell from control panel or motors.

In auto-operation of a number of chillers with increase in load, chillers should first be tested individually and later on in group

During commissioning, Manufacturer's qualified commissioning engineers must be given the responsibility specially for central Plants.

To check the duct/water line design, outlet air/water flow must be recorded at every crucial point and adjustment should be made to balance the air/water flow.

7.16 MAINTENANCE ASPECT

7.16.1 General:

An equipment or a machine is a capital asset. Its loss in capital value over time is theoretically recovered from the worth it contributes to the operations of the organizations; the investment is amortized. How fast the equipment loses its value is, in part, a function of the maintenance program. The adoption of a proper maintenance policy of all the equipment is extremely essential.

The maintenance costs are lower when an equipment is new. These cost, increase with age because more work is needed to maintain a given level of performance.

7.16.2 Maintenance policy:

There are two types of maintenance policies

- Break down maintenance
- Preventive maintenance

Break down maintenance policy involves the repair, replacement and operation of standby equipment, when the operating equipment has failed completely. For small and cheap equipment, replacement after failure is most economical.

Repair of break down machine is the most obvious way of rendering the operational system functional. But without standby systems, the repair time may result in significant idle time costs, and high repair costs. It may reduce the efficiency, which may result low productivity.

Preventive maintenance is used to reduce the frequency and magnitude of major repairs. Break-down maintenance does not consider the reduced efficiency and functionality, wear and tear of an equipment with age and use.

Preventive maintenance calls for taking an equipment for repair at planned intervals, so that uncalled for break-down could be prevented. Preventive maintenance helps in prolonging the life of the equipment (of the order of 3-4 times) and reduction in unexpected break-downs, on the other it ensures the accuracy of the equipment thus maintaining the quality and continuity of operations.

The repairs which are carried out at planned interval under preventive maintenance can be broadly classified in four stages :

- Inspection
- Small repair
- Medium repair
- Complete over haul

The objective of preventive maintenance are :

- To attain longer life

- To increase useful time
 - To maintain the design level of performance
- So preventive maintenance is one of the most important policies for equipment.

7.16.3 Periodic Maintenance Schedule

Log Book should be maintained daily with special reference to unusual sound and smell and this should be checked by senior maintenance engineer at the end of every day but definitely 2/3 times a week. Any unusual finding should be referred to the Manufacturer's representative.

Dust (of course water) is the greatest enemy of electrical equipment. The plant room must be made dust free as well as to keep the load of AHU normal, filters should be attended as per recommendation of the filter manufacturers.

Panel Boards must be opened atleast once a month to check for spider nets, rats, cockroaches or any other insects.

Once the system is declared for continuous service, the installer should provide at least five complete sets of operation and maintenance manual to the owners operating and maintenance personnel.

The copy of the operation and maintenance manual should be carefully kept in the departmental library, Sub-Divisional Engineer's Office, Executive Engineers Office, Superintending Engineers Office and with the departmental maintenance personnels.

Manufacturer's Maintenance Manual should be meticulously followed.

A check list should be prepared which lists the required maintenance service operations and the time at which they are to be performed, the sample of which are given below :

Daily Maintenance

- Clear all dust, dirt, water etc. of the whole equipment and of all auxiliaries of the whole air-conditioning system properly.
- Check compressor oil level.
- Observe the oil pressure. The oil pressure gauge reading should be approximately 20 to 35 PSI above the suction pressure gauge reading. If the oil pressure is low, clean or change the oil filter.
- Check oil temperature and reset control point, if necessary.
- Check oil leaks, if there is any, tighten bolts as necessary.
- Check supply air pressure for pneumatic control centre.
- Check operation of L.P. & H.P. cut-out control, reset if necessary.
- Check low chilled water, entering and leaving chilled water temperature thermostat operation, adjust or change if necessary
- Check the chilled and condenser water flow and adjust as required.
- Check Gear oil pressure and temperature
- Check and clean motor starters and adjust if necessary.
- Clean the pump surroundings, blockage of drain pipes and over flow lines, water trays etc.
- Clean and check refrigerant air driers.
- Check make up water lines and tank, float valve for proper functioning.
- Check the operation of all pneumatic control valves in the chilled water lines of the AHUS. Purge air from the chilled water and condenser water pipe lines. In case of improper functioning of the valve operators and actuators replace it.
- Check operation

Weekly Maintenance

- Check the condition of the air filters and air handling equipment, clean or replace filter if necessary.
- Check the general operating conditions, system pressures, refrigerent sight glass etc.
- Check the reservoir (chemical) content level and the feed pump operation. Mix chemical and fill reservoir if necessary.
- Check air flow and adjust as necessary.
- Check the operation of the Air-compressor operation.
- Check the compressor oil level, if it is high, drain the excess oil. If it is low charge oil. Follow the oil charging procedure in the manual.
- Check for oil leaks, if there is any, tighten bolts as necessary. Stop the compressor and check the shaft seal for excessive oil leakage. If found, check the seal with a refrigerent leak detector. Make necessary arrangement to change gaskets/seals.
- Check that the H.P. & L.P. Gauge readings tally with suction and discharge temperature of the compressor. In case of any discrepancy, calibrate the gauge with a correct gauge.
- Check chilled & condenser water flow and adjust as required.
- Check operation of air vent. In case of improper operation, replace.
- Vent all chilled water coils of AHUS and preceding coils.
- Vent chilled and condenser water boxes of the chillers.
- Check the drive motor current and line voltage. Take correctiv e steps for any abnormal conditions.

Monthly maintenance

- Lubricate/grease the fan motor bearings as necessary. Obtain and follow the manufacturer's lubricant specification and bearing care instructions.
- Check fan belt tension and alignment.
- Tighten all fan sheaves and pulleys. If found to be loose, check alignment before tightening.
- Check the operation of the oil heater.
- Check the oil level on both the sleeve bearing, charge oil if level is low.
- Check the operation of the oil pump. Measure motor current and check for any un usual heating in any part of the bearing or motor.
- If necessary change bearing.
- Check oil pump pressure, if it is low change oil pump if necessary.
- Check the operation of the Refrigerent transfer pumps by transferring refrigerent in the storage tank. In case of any trouble take necessary correcting steps as per manual.
- Check the operation of the starter and adjust it. In case of any difficulty, open up the starter and remove the difficulty. After normal operation, disconnect supply to the starter and check for any abnormal heating of parts : Check the contacts, service the contacts and remove if necessary.
- Check level of refrigerent in the sight glass. If the level is low charge refrigerent as per instruction of the manual.
- Thorough test the entire system for any refrigerent leakage with a reliable leak detector, leaks, if any found should be removed.
- Check the operation of the current limiting control and all relays in the control.
- Check the relief valve.
- Drain, clean and refill basin of the cooling Tower. Inspect and clean suction screens, nozzles.
- Check gear box oil level of cooling tower motor, change the oil if the colour has changed.
- Check pump and motor coupling condition and alignment.
- Muggit motor winding and record readings.

- Check and clean cooling and precooling coils.
- Check and clean all grills and diffusers.
- Check air flow and adjust the dampers as required. Adjust the vertical/horizontal bars for proper air distribution. Check the function of Damper motor.
- Measure room temp and relative humidity and adjust A.H.U. leaving air temp. if necessary by adjusting chilled water flow.
- Check operation of return air thermostat and adjust if necessary.
- Clean kitchen hoods both from inside and outside.
- Clean all strainers and replace where necessary.

Quarterly Maintenance

- Check the condition of the duct work including supply air control dampers and fire damper.
- Check all types of insulation, repair/replace if necessary.
- Clean dust, dirt, water etc. of the ducts and water pipe lines.

Annual Maintenance

- If the colour of the lubricating oil of compressors, gears & motor, has changed, replace it.
- Check that the pre-rotation vanes remain closed before start-up. The vanes should start opening when the compressor is on the running winding. Check that the vanes fully open when the compressor is on the running winding.
- Spring isolators should be checked for proper leveling, adjust if required.
- Check calibration and operation of all sensors, controllers and thermostats.
- Check all volume control dampers and adjust if necessary.
- Check all face and by pass dampers for proper operation.
- Check the actuator, recalibrate if necessary or replace.
- Drain all circuits of the water condensing system. Inspect the condenser piping and seals or sludge from the tubes of the condenser.
- Drain the cooling tower or condenser, flush the pumps and sump tanks. Remove any rust or corrosion in the metal surface of cooling Tower/condenser and repaint the rusted and corroded areas.
- Inspect all motor and fan shaft bearings for signs of wear. Check shafts for proper end-play adjustment.
- Replace worm or frayed fan belts.
- Clean all water strainers.
- Valve off the supply and return water connections of a water cooled condenser. Allow the condenser to remain full of water during the off season. A drained condenser shell is more likely to rust and corrode than one that is full of water. If the condenser will be subjected to freezing temperatures, drain the water and refill it with an antifreeze solution.

Seasonal start up (in case of central/package system)

- Perform all annual maintenance on the air handling system and other related equipment.
- Full the water sump of the cooling tower or evaporative condenser.
- Open the shut off valves of a water cooled condenser.
- Make sure that the liquid line solenoid valve(s) is on automatic control.
- Open the liquid line shut off valve.
- Back seat the compressor suction and discharge valves.
- Close the system master electrical disconnect switch. Start the system.
- After the system has operated for 15 to 20 minutes, then check the compressor oil level sight glass, oil pressure and the liquid line sight glass. If satisfactory, read-just the system temperature controller to the proper temperature setting.

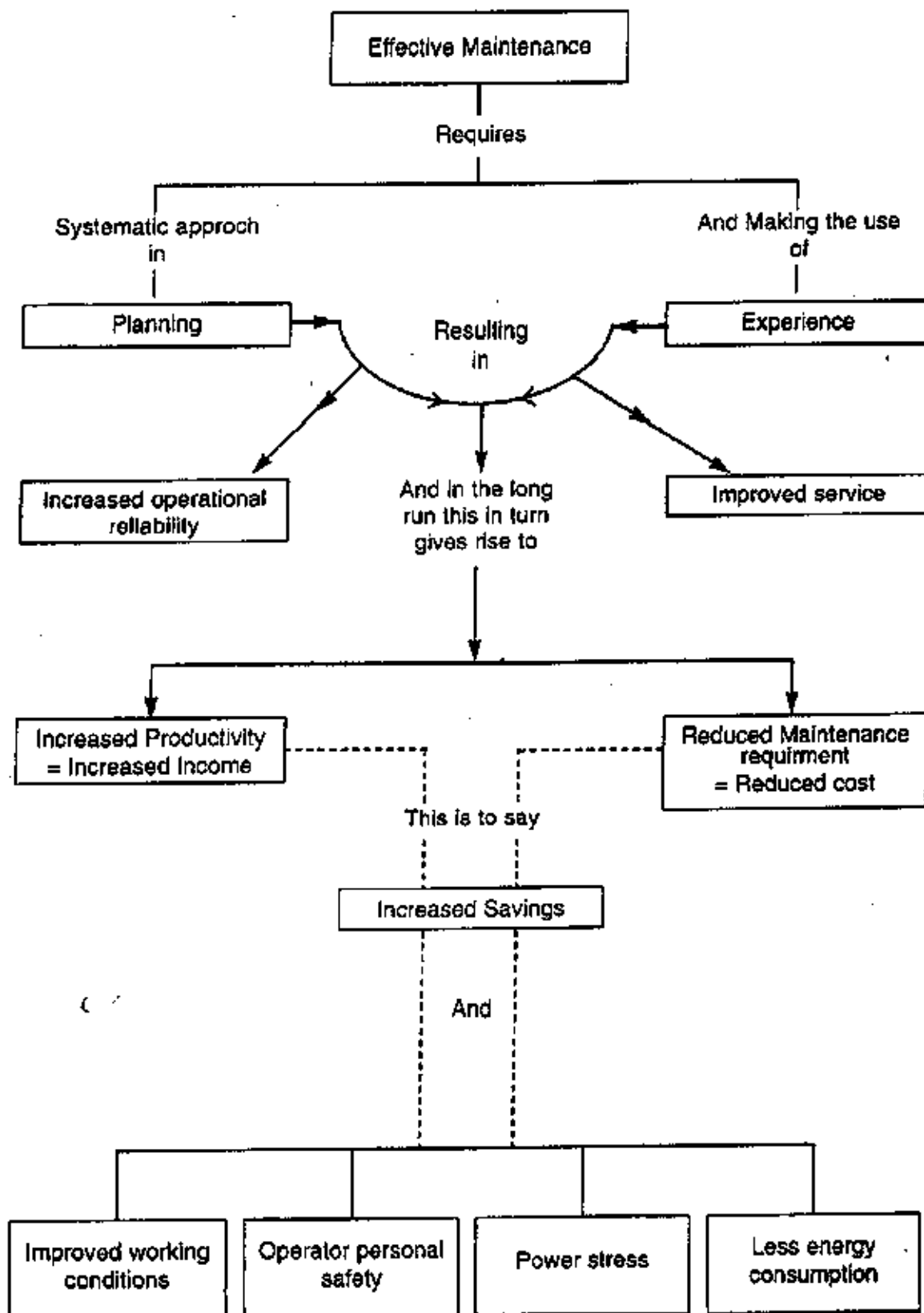


TABLE - F
Required Mechanical Ventilation Air

Occupancy Classification	Required Ventilation Air (l/s) per Person Unless Otherwise (Indicated)
Assembly	
Food Services	
Bars and cocktail lounges	25
Cafeterias, fast food centres	17.5
Dining rooms	17.5
Kitchens	15 ^a
Museums	
Exhibit halls	17.5
Warehouses	5
Workrooms	10
Public(meeting)facilities	
Assembly rooms	17.5
Ballrooms	17.5
Conference rooms	17.5
Lobbies	07.5
Theaters	
Auditoriums (no smoking)	17.5
Lobbies, foyers and lounges	17.5
Projection booths	10 ^a
Stages TV and movie studios	7.5
Ticket booths	10
Offices	
Computer rooms	5
Conference rooms	17.5
Duplicating and printing rooms	2.7 l/s per m ² of floor area
Office space	12.5
Waiting rooms	17.5
Photo studios	
Camera rooms, stages	7.5
Darkrooms	10
Research institutes	
Laboratories	17.5
Laboratories, radionuclide chemically and biologically toxic	17.5 ^a
Educational	
Schools	
Auditoriums	17.5
Corridors	12.5
Classrooms	12.5
Gymnasiums	17.5
Laboratories	7.5
Libraries	5
Lunchrooms dining halls, common rooms, lounges	17.5
Music rooms, rehearsal rooms	17.5
Training shops	17.5
Hospitals, nursing and convalescent homes	
Autopsy rooms	12 air changes per hour ^a
Delivery rooms, trauma rooms	15 air changes per hour

TABLE - F Contd)

Laboratories	6 air changes per hour
Operating rooms	20 air changes per hour
Patient rooms	2 air changes per hour
Pharmacy, medication rooms	4 air changes per hour
Physical therapy areas and treatment rooms	6 air changes per hour
Recovery and intensive care rooms	6 air changes per hour
Soiled utility rooms janitor closets	10 air changes per hour
Residential	
Dwelling units	
General living areas, bedrooms, all other rooms	5 l/s per room
Kitchens, bath rooms, toilets	50 l/s per room ^b
Special areas	
Elevators	7.5
Exits and corridors	0.1 l/s per m ² of floor area
Lockers and dressing rooms	17.5 ^b
Public bathrooms	37.5 l/s per water closet or urinal ^b
Nonpublic bathrooms	25 l/s per water closet or urinal ^b
Utility rooms	0.1 l/s m ² of floor area
Survival shelters	2.5

Note :

- a) Return air shall be exhausted in accordance with Bangladesh National bldg code, chap-3, Art 3.7.4.1.
- b) Recirculation shall be in accordance with the Bangladesh National Bldg code, chap-3, Art 3.7.3.6. except that non public bathrooms with a bathtub and/or shower shall not be recirculated and shall be mechanically exhausted.

Table - G
Maximum Allowable Contaminant Concentrations

Contaminant	Annual Average (arithmetic mean) µg/m ³	Short Term level (not to be exceeded more than once a year µg/m ³	Averaging Period (hours)
Particulates	60	150	24
Sulfur oxide	80	400	24
Carbon monoxide	20,000	30,000	8
Photochemical oxidant	100	500	1
Hydrocarbons (non including methane)	1,800	4,000	3
Nitrogen oxides	200	500	24
Odour	-	Essentially unobjectionable ^a	

Note : a. Judged unobjectionable by 60 per cent of a panel of 10 untrained subjects.

Appendix-A

Air Conditioning Load Estimate Format

SHEET _____ DATE _____
 PREPARED BY _____
 NAME OF JOB _____
 LOCATION _____

OFFICE _____
 PROP NO. _____ JOB NO. _____
 APPROVED _____

SPACE USED FOR _____				
SIZE	X	SQ FT X		CU FT
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP DIF	FACTOR	BTU/HOUR
SOLAR GAIN - GLASS				
GLASS	SQ FT X	X		
GLASS	SQ FT X	X		
GLASS	SQ FT X	X		
GLASS	SQ FT X	X		
SKYLIGHT	SQ FT X	X		
SOLAR & TRANS. GAIN - WALLS & ROOF				
WALL	SQ FT X	X		
WALL	SQ FT X	X		
WALL	SQ FT X	X		
WALL	SQ FT X	X		
ROOF SUN	SQ FT X	X		
ROOF SHADE	SQ FT X	X		
TRANS. GAIN - EXCEPT WALLS & ROOF				
ALL GLASS	SQ FT X	X		
PARTITION	SQ FT X	X		
CEILING	SQ FT X	X		
FLOOR	SQ FT X	X		
INFILTRATION	CEM X	X	1.09	
INTERNAL HEAT				
PEOPLE		X		
POWER	HP OR KW X			
LIGHTS	WATTS X		3.4	
APPLIANCES ETC.		X		
ADDITIONAL HEAT GAINS		X		
SUB TOTAL				
STORAGE	SQ FT X	X ()		
SUB TOTAL				
SAFETY FACTOR _____ %				
ROOM SENSIBLE HEAT (RSR) ■				
SUPPLY DUCT HEAT GAIN	SUPPLY DUCT LEAK LOSS	% FAN H.P.	%	
OUTDOOR AIR	CEM X	F X	BF X 1.09	
EFFECTIVE ROOM SENSIBLE HEAT (ERSH) ■				
LATENT HEAT				
INFILTRATION	CEM X	GRLB X 0.68		
PEOPLE	X			
STEAM	LB/HR X 1050			
APPLIANCES ETC.				
ADDITIONAL HEAT GAINS				
VAPOR TRANS.	SQ FT X 1/100 X	GRLB X		
SUB TOTAL				
SAFETY FACTOR _____ %				
ROOM LATENT HEAT (RLH) ■				
SUPPLY DUCT LEAKAGE LOSS		%		
OUTDOOR AIR	CEM X	GRLB	BE X 0.68	
EFFECTIVE ROOM LATENT HEAT (ERLH) ■				
EFFECTIVE ROOM TOTAL HEAT (ERTH) ■				
OUTDOOR AIR HEAT				
SENSIBLE	CEM X	F X	(1 - BF) X 1.09	
LATENT	CEM X	GRLB X	(1 - BF) X 0.68	
RETURN DUCT HEAT GAIN	% RSH	RETURN DUCT LEAKAGE GAIN	% RSH	
RETURN AIR OR BLOW THRU FAN		H.P. X 2545		
GRAND TOTAL HEAT (GTH) OR DEHUMIDIFIER LOAD ■				
PUMP H.P.	% GTH	PIPES HEAT GAIN	% GTH	
REFRIGERATION LOAD ■				

ESTIMATE FOR	LOCAL TIME SUN TIME	PEAK LOAD	LOCAL TIME SUN TIME
EQUIPMENT OPERATION HOURS/DAY			
CONDITIONS	EG	WB	%RH
OUTDOOR (OA)			
ROOM (RM)			
DIFFERENCE	XXX	XXX	XXX
OUTDOOR AIR			
VENTILATION	PEOPLE X	CFM/PERSON	
	SQ FT X	CFM/SQ FT	
CFM VENTILATION ■			
INFLTRATION			
SWINGING, REVOLVING DOORS	PEOPLE X	CFM/PERSON	
OPEN DOORS	DOORS X	CFM/DOOR	
EXHAUST FAN			
CRACK	FEET X	CFM/FT	
CFM INFILTRATION ■			
CFM OUTDOOR AIR THRU APPARATUS ■			
APPARATUS DEWPOINT & DEHUMIDIFIED AIR QUANTITY			
ESHF	EFFECTIVE SENSIBLE HEAT FACTOR	ERSH	ERTH
AOP DEHUM. RISE	INDICATED AOP = _____ F	SELECTED AOP = _____ F	
	(1 - BF) X (T _{RM} - F - T _{AOP} - F)		
DEHUM. CIM		ERSH	CFM _{OA}
	1.09 X	F _{DEHUM RISE}	
SUPPLY AIR QUANTITY			
OUTHER TEMP. DIFT.	RSR	F (RM-OUTLET AIR)	
	1.09 X	CFM _{OA}	
SUPPLY CIM	NSH	F _{DESIRED DFF}	CFM _{SA}
	1.09 X		
BYPASS CIM	CFM _{SA}	CFM _{DA}	CFM _{RA}
IF THIS IS TOO HIGH DETERMINE SUPPLY CFM FOR DESIRED OFFER ENERGY SUPPLY AIR QUANTITY FORMULA.			
RESULTING ENT & LVD CONDITIONS AT APPARATUS			
T _{RM}	F +	CFM _{OA} X (T _{OA} - F - T _{RM} - F)	T _{EDB} - F
		CFMT	
T _{AOP}	F +	BF X (T _{EDB} - F - T _{AOP} - F)	T _{LDB} - F
FROM PSYCH CHART : T _{WB} - F T _{LWB} - F			
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR USE SUPPLY CFM WHEN BYPASSING RETURN AIR ONLY USE DEHUMIDIFIED CFM			
NOTES			