Arab Republic of Egypt
Ministry of Housing, Utilities and Urban Development
Housing & Building National Research Center

Egyptian Code
Concerning Design Criteria and Rules
Of
Potable Water and Sanitary Drainage Treatment Plants and Pumping Stations
ECP 101 – 1997

Third part: 101/3
Potable Water Treatment Plants

Standing Committee for the preparation of
Egyptian Code
Concerning Design Criteria and Rules
Of
Potable Water and Sanitary Drainage Treatment Plants and Pumping Stations

Edition 2008

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Ministry of <u>Housing, Utilities</u> and Urban Development

Minister Office

Ministerial Resolution
No. (52)/1998
<u>Regarding the Egyptian Code for Potable Water Treatment Plants</u>

Minster of Housing, Utilities and Urban Development

- After perusal of Law No 6/1964 regarding design criteria and rules of construction and building works
- And, Presidential Decree No. 46/1977 regarding Public Authority for Housing, Building and Urban Planning Research Center
- And, Ministerial Decree No. 79/1991 and Ministerial Decree No. 318/1992 on formation of the standing committee for the preparation of Egyptian Code Concerning Design Criteria and Rules of Potable Water and Sanitary Drainage Treatment Plants and Pumping Stations.
- And, Ministerial Decree No. 492/1996 on formation of the main committee on design criteria and rules of construction and building works.
- And, the note presented from chairman of standing committee for Design Criteria and Rules of Potable Water and Sanitary Drainage Treatment Plants dated 22/02/1988.

Decided the following:

Article (1): Part (3) of Egyptian Code Concerning Design Criteria and Rules of Sanitary Drainage Pumping Stations shall be applied.

Article (2): Concerned bodies as mentioned in Law No. 6/1964 shall adhere to implement provisions of this code.

Article (3): Housing & Building Research Center shall publish, define and train on provisions of this code.

Article (4): This decree shall be published in the Egyptian Gazette and shall enter into effect after six months of its publication.

Issued on: 01/03/1998

Minister of Housing, Utilities, and Urban Development

Signature

Prof. Dr. Eng. Mohamed Ibrahim Sulayman

Introduction

Due to the huge investments in the filed of infra structural of water supply and sanitary drainage projects, as these projects represent the urgent priorities in development programs, and due to the change of urban styles in our community, so it is necessary to chose systems and methods suitable for water treatment works.

As water-supplying projects are carried out according to special conditions and specifications followed by each administrative entity in cooperation with the authorities and bodies implementing these works, this has led to a multiplicity of jurisprudence in the preparation of design criteria and rules for the sanitary drainage works (pumping stations and treatment plants) due the multiplicity of agencies working in this area, which led to differences in the criteria and rules to be followed for the same type of works.

Therefore, it was issued decree of Minister of Construction, New Urban Communities, Housing and Utilities No. 79/1991 and No. 318/1992 on formation of the of the standing committee for the preparation of Egyptian Code Concerning Design Criteria and Rules of Potable Water and Sanitary Drainage Treatment Plants and Pumping Stations under Law No. 6/1964.

The committee prepared the code draft for water treatment plants and pumping stations and distributed it to the concerned bodies, such as general authorities, universities, consultation offices, research centers and institutes, armed forces, contracting companies and others, to give their opinion, and then a public symposium was held to discuss the various opinions. Based on these discussions, this code was prepared in its final form.

This code has been issued by the Ministerial Decree No. (52)/1998. Housing & Building Research Center shall publish, identify and train on this code for the development of potable water projects in the Republic. Any subsequent amendments thereof shall be an integral part of this code.

God grant us success

Minister of Housing, Utilities, and Urban Development

Signature

Prof. Dr. Eng. Mohamed Ibrahim Sulayman

Preface

Due to the successive development and steady expansion in the filed of constriction, building and reconstruction at a national scale, it was issued Law No. 6/1964 regarding design criteria and rules of construction and building works (Article 1), where Ministry of Housing, Utilities and Urban Communities is responsible to implement this work.

From this standpoint, Housing & Building National Research Center in accordance with the Presidential Decree No. 63/2005, shall publish, update and train on the code, work items specifications and technical specifications of construction materials in order to comply with the international trends and meet the local conditions so that the codes work as a guide in the field of construction and building works and also to guide the engineers and the workers in the construction filed.

To ensure achieving the desired objectives of these codes, the main committee formed from representatives of the Ministry of Housing, Utilities and Urban Communities and the ministries concerned with construction and building works, as well as university professors, experts and consultants in this field, shall develop the general approach in all areas related to construction and building works also sets the general policy and planning for method of work on a permanent basis, form the standing committees and specialized subcommittees of professors, consultants and senior engineers in the fields of application related to construction and building works whom have long recognized experience in this field from outside and inside the center.

The Centre benefited from all the expertise available at home and outside in the preparation of codes in order to support and increase the effectiveness of the preparation of codes. The various committees were the melting pot of all knowledge and expertise, and a model for the close link between the Centre, Universities, production sectors and services, and in furtherance of national participation and contribution in this national work that contributes to increase the effectiveness of the development of scientific planning.

Perhaps the most important controls to measure the volume of work in the codes, is to record what is being achieved to be untroubled of the effort done and know our location on the road through what has been prepared and issued from codes and specifications contained in the attached tables, note that the codes have being updated at a continuous basis according to the new scientific, technological developments and in accordance with the experiences gained from conditions of application.

God is the source of our strength in this regard,,

Chairman
Housing & Building National Research Center
Prof. Dr. Eng. Omima Ahmed Salah Eldin

List of Construction and Building Codes issued from the Center

No	Code Name	Code No
1	Design Criteria and Rules of Potable Water and Sanitary Drainage Treatment Plants and Pumping Stations:	101
	Volume 1: Sanitary Drainage Pumping Stations	101/1
	Volume 2: Sanitary Drainage Treatment Works	101/2
	Volume 3: Potable Water Purification Plants	101/3
	Volume 4: Potable Water Pumping Stations.	101/4
2	Design and Execution of Pipelines for Potable Water and Sanitary Drainage Networks	102
3	Urban and Rural Roads Works:	104
	Part (1): Preliminary Studies for the Roads	104/1
	Part (2): Traffic Studies	104/2
	Part (3): Engineering Design	104/3
	Part (4): Roads Materials and their Test	104/4
	Part (5): Bridges Design and Construction	104/5
	Part (6): Constructional Design of Roads	104/6
	Part (7): Surface and Underground Drainage for the Roads	104/7
	Part (8): Road Equipments.	104/8
	Part (9): Rules of Road Works Inside and Outside Cities.	104/9
	Part (10): Roads Maintenance	104/10
4	Calculation of Loads and Strengths in Construction and Building Works	201
5	Soil Mechanics, Design and Execution of Foundations:	202
	Part (1): Study of the Site	202/1
	Part (2): Laboratory Teats	202/2
	Part (3): Shallow Foundations	202/3
	Part (4): Deep Foundation	202/4
	Part (5): Foundations on soils with problems	202/5
	Part (6); Foundations subject to Vibrations and Dynamic Loads	202/6
	Part (7): Retaining Structures	202/7
	Part (8): Slope Stability	202/8
	Part (9): Earth Works and Dewatering	202/9
	Part (10): Foundation on Rocks	202/10
	Part (20): Technical Terminology	202/20

6	Design and Execution of Reinforced Concrete Constructions	203
7	Design Criteria and Rules of Building Works: Part (1): Retaining Walls Part (3): Bearing Walls Part (4): External non-bearing walls used as external curtains. Part (5): Bearing Walls used as Partitions Part (6): Arches, Domes and Vaults Part (7): Resistance of building with bearing walls to earthquakes "Constructional and Architectural Rules" Part (8): Technical Terminology	204 204/1 204/3 204/4 204/5 204/6 204/7 204/8
8	Steel Construction and Bridges	205
9	Design Criteria and Rules of Sanitary Installations Engineering in Buildings: Part (1): Sanitary Installation of Buildings Part (2): Water supply and sanitary drainage treatment in small communities. Part (3): Supply of Hot water and Swimming Pool Works. Part (4): Equipping of kitchens, hospitals and disposal of wastes.	302 301/1 301/2 301/3 301/4
10	Design Criteria and Rules of Electrical Connections and Installations in Buildings: Part (1): Basics Part (2): Basics Part (3): Tables and Annexes Part (4): Earthing Part (5): Prevention of lightning Part (6): Power Factor Correction Part (7): Harmonics Part (8): Conductors and Starters used in control of 3-phase induction motors. Part (9): Lighting Control Part (10): Emergency Generators	302 302/1 302/2 302/3 302/4 302/5 302/6 302/7 302/8 302/9 302/10
11	Design Criteria and Rules of Electrical and Hydraulic Elevators in Buildings (English)	303
12	Design Criteria and Rules of Electrical and Hydraulic Elevators in Buildings (Arabic)	303

13	Air Cooling and Conditioning Volume (1): Air Conditioning Volume (2): Cooling Volum2 (3): Control and Electricity Works	304 304/1 304/2 304/3
14	Design Criteria and Rules of Protection of Constructions from Fire Part (1): Design Criteria and Rules of Protection of Constructions from Fire. Part (2): Building Service Systems Requirements to Reduce fire Risks Part (3): Fire Detection and Alarm Systems.	305 305/1 305/2 305/3
15	Design Criteria and Rules of External, Internal and Special Painting	401
16	Design of External Areas and Building for the Disabled.	601

List of Annexes and Dictionaries Complementary for the Codes

No	Annex Name
1	Design aids with examples according to Egyptian Code
2	Concrete Materials Lab Tests Guide
3	Dictionary of Soil Mechanics and Foundation Engineering (3 Languages)
4	Construction Data and Drawings Preparation Guide

List of Works Specifications and Contract Documents Issued from the Center

No	Specification Name	Code No
Contract Documents		901
1	Consultation, studies and design contract	901/1
2	General conditions of contracting works contract	901/2
3	Engineering consultation services contract for supervision of implementation "Construction Department"	901/3
4	Engineering consultation services contract for studies, designs and continuous supervision of implementation.	901/4
5	Design and implementation contract (financed by the owner)	901/5
Works Specifications		902
6	Sanitary Works Specifications	902/1
7	Marble Works Specifications	902/2
8	Architectural Woodworking Specifications	902/3
9	Aluminum Works Specifications	902/4
10	Earth Works Specifications (Excavation and Backfilling)	902/5
11	Soil Insulation Specifications	902/6
12	Reinforced Concrete Works Specifications	902/7
13	Painting Works Specifications	902/8
14	Public expenditure and financial commitments specifications	902/9
15	Plastering Works Specifications	902/10
16	Architectural blacksmith works specifications	902/11
17	Specifications of electrical connections and installations (Part 1 and Part 2)	902/12
18	Specifications of thermal insulation work "Design criteria and rules".	902/13

General Introduction

Cities and villages water supply projects, as well as treatment and disposal of sanitary drainage liquids in modern communities, represent urgent priorities in development programs, where many of Egyptian cities and most villages suffer from non-existence of all sanitary drainage services for disposal of the liquid waste. It was severely increased and had inverse impact with the supply of the cities and villages with fresh water and increase of population.

So, the State and its concerned authorities give special interest to potable water supply and sanitary drainage projects. Due to the change of urban patterns, it is important to choose appropriate systems for the purification of drinking water and liquid waste treatment.

As sanitary drainage projects are carried out according to special conditions and specifications followed by each administrative entity in cooperation with the authorities and bodies implementing these works, this has led to a multiplicity of jurisprudence in the preparation of design criteria and rules for potable water implementation works (pumping stations and purification plants) and also for the sanitary drainage projects (pumping stations and treatment plants) due the multiplicity of agencies working in this area, which led to differences in the criteria and rules to be followed for the same type of works.

Therefore, it was issued decree of Minister of Construction, New Urban Communities, Housing and Utilities No. 79/1991 on formation of the of the standing committee concerning design criteria and rules of potable water and sanitary drainage treatment plants and pumping stations.

The committee has divided the Code into four volumes:

Volume 1: Sanitary Drainage Pumping Stations

Volume 2: Sanitary Drainage Treatment Plants

Volume 3: Potable Water Purification Plants

Volume 4: Potable Water Pumping Stations.

Volumes 1, 2, 3 and 4 are divided into three chapters:

Chapter (1): The Studies

Chapter (2): Design Criteria

Chapter (3): The Rules

This code indicates design criteria and rules of water treatment plants and pumping stations. It also indicates the maximum requirements that must be taken into considerations in design, implementation and achievement efficiency of sanitary drainage projects. This should not conflict with the recommendations and conditions added by the Consultant suitable and appropriate for the projects. Subjection of the design and implementation to the provisions of this code does not exempt from any legal responsibilities and obligations.

Thanks and Recognition

Standing committee for the preparation of Egyptian Code Concerning Design Criteria and Rules of Potable Water and Sanitary Drainage Treatment Plants and Pumping Stations extends thanks to Housing & Building Research Center for its effort and facilities provided for production of this work in a decent form.

The committee also extends recognition to the authorities who have contributed their opinion in enriching this work through discussions and technical views, they are:

(1) National Authority For Potable Water And Sanitary Drainage
(2) Cairo General Organization for Potable Water.
(3) Faculty of Engineer   Ain Shams University
(4) Faculty of Engineer   Zagazig University
(5) Consultant office   Kimo Nix
(6) Nasr General Contracting

Chairman of Standing Committee
Prof. Dr. Eng. Ibrahim Hilal El Hatab

Contents

Page

Chapter 3: Implementation Terms

Figures index **Page No.**

Chapter 1: Studies

Chapter 2: Design

Page No.

Tables index **Page No.**

Page No.

(F)

Chapter one
Studies

Introduction

When starting to design potable water treatment works for a city, village or compound, it needs to conduct the followings studies:

1- population and different activities
2- water consumption rates
3- Design disposals.
4- Water resources
5- Water properties.
6- Types and phases of treatment
7- Site selection.
8- Survey works.
9- Soil studies.
10- General layout of the station.
11- Methods of control and protection.

1- Population and different activities

1-1 Estimation of Population

Population rate of a city are estimated for a period from 3 to 50 years based on the following:

A- Existing city.

B- New city or new urban community.

In the first instance, population are predicted by determining the phase in which the city is growing whether by progressive, stable or decreased increase. This is subject to what will be clarified regarding census in the future. Whereas in instance of new urban communities, growth phases are considered according to the layout of this compound for different phases of growth and its terms, or the following phases and its order are sought to forecast it.

1-1-1 Start-up and prosperity stage

This stage characterized by increased rate of population in the form of geometrical increase.

1-1-2 Stability stage

In this stage population attraction factors are stable and requires fixed population expansion and the population growth will be calculate by the arithmetic method that ranges from 10 to 15 years.

1-1-3 Saturation stage

It is the reach to the decreased increase of population growth due to stop of attraction factors or as a result of construction of other adjacent residential communities with stronger attraction factors. The term of this phase ranges between 15-20 years. Figure (1-1) demonstrates the curve of the population growth of this dependent phase.

1-2 Future Estimation of Population

Population at the end of design periods is estimated by using the statistics performed by the governmental bodies concerned with population studies in order to know the current expectations of future population. In order to achieve future estimation of population designer shall apply one of the following methods:

1-2-1 Arithmetic Increase

The applied equation is:

$$P_n = P_1 + K_a (t_n - t_1) \quad \text{..} \quad (1)$$

This method is represented graphically by a straight line.

1-2-2 Geometrical Increase

The applied equation is:

$$L_n\ P_n = L_n\ P1 + K_g\ (t_n + t1) \ldots\ldots\ldots\ldots\ (2)$$

It is represented graphically by an increasing curve of first order

1-2-3 Decreasing Rate of Increase

The applied equation in this method is:

$$P_n = (S - P1) + e^{-kd}\ (tn - t1) \ldots\ldots\ldots\ldots\ (3)$$

It is represented graphically by decreasing curve of first order. The symbols used in equations 1, 2 and 3 are as follows:

P_n: The population served by the project in the target year.

P_1: Last population for the region taken according to Mobilization and Statistics statement.

K_a: Annual population increase rate (fixed rate)

K_g: Annual population increase rate in the geometric method (increased rate)

K_d : Decreased annual population increase rate (decreased rate).

S : Maximum value of expected population (saturation limit)

$(t_n - t_1)$: Time period served by the project.

$\ln$: Natural logarithm for the base (e) = 2, 7

Fig (1-1) represents population growth curve for the city and shows the relation between the population and the time periods that represented by each of the above methods.

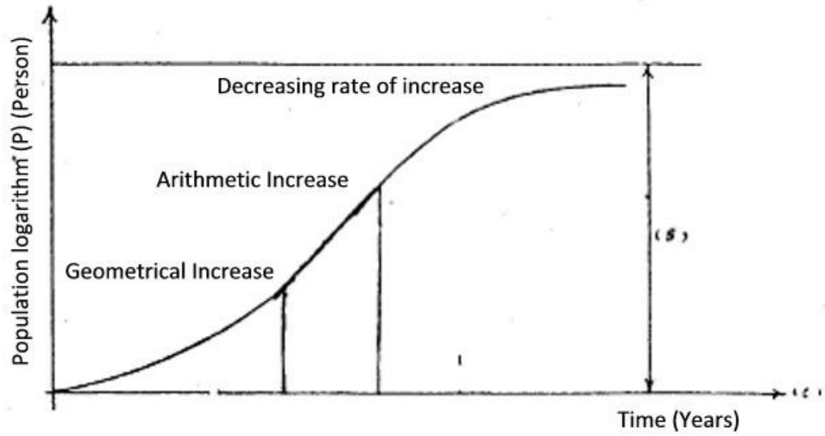


Fig (1-1) Population growth curve for the city

Future census can be calculated by using the following methods:

1-2-4 Graphical Extension Method

It is an approximate method from which future census is deduced by drawing growth curve of the area in the past; them make an extension from it to deduce the census in the targeted year.

1-2-5 Graphical Comparison Method

In which the curve of the population growth of the subject area is drawn similar to the curve of population growth of city (peer) which has more census, then the curve similar to the curve of the population increase of the big city is expanded. Thus, the required population census can be deduced.

2- Rates of Water Consumption

It refers to the rates of water consumption by Liter/ Individual/ Day.

These rates differ by different seasons and months and within the 24 hours of the day. In order to face these changes in consumption rates, it is possible to define different consumption rates and deduce the average of daily consumption along the year as a measure for the rest consumption rates. The following is a definition for the different consumption rates:

2-1 Average of Daily Consumption

It is calculated by dividing total water consumption during the year by the days of the year.

2-2 Maximum Monthly Consumption

Specify the month that has maximum consumption and measure the average daily consumption during this month and the result will be the maximum monthly average which amounts (1,25-1,50) of average of daily consumption.

2-3 Maximum Daily Consumption

Specify the month that has maximum consumption during the year, then specify the day within the month which has maximum consumption and the result will be the maximum daily average which amounts (1,6-1, 8) of the average of daily consumption.

2-4 Maximum Hourly Consumption

Specify the day that has maximum consumption during the year that gives the maximum daily consumption, then draw consumption curve during the hours of this day, thus the maximum hourly consumption is measured which amounts 2,5 of the average daily consumption.

The importance of studying consumption rates is in determining different discharges used in designing different works for water supply where (Maximum Monthly Consumption) in designing treatment works, (Maximum Daily Consumption) in designing main and secondary lines, storage works for the network, whereas (Maximum Hourly Consumption) is used in designing distribution lines in the network as well as designing service connections to homes.

Figures (1-2), (1-3) demonstrates the relation between different consumption rates.

Figures (1-2), (1-3) shows the following:

B/A= (1,25-1,5)

C/A= (1,6-1,8)

D/E= 1,50

D/A= 2,50

Estimation of increase in future consumption rates.

To recognize future consumption rates, the following equations shall apply:

(4) Percent increase= $[(P_n)\ 0.125-1]\times\ 100$

(5) Percent increase= $[(P_n)\ 0.11-1]\times\ 100$

Equation (4) applies in case there are no gauges for water consumption.

Equation (5) applies in case there are gauges for water consumption.

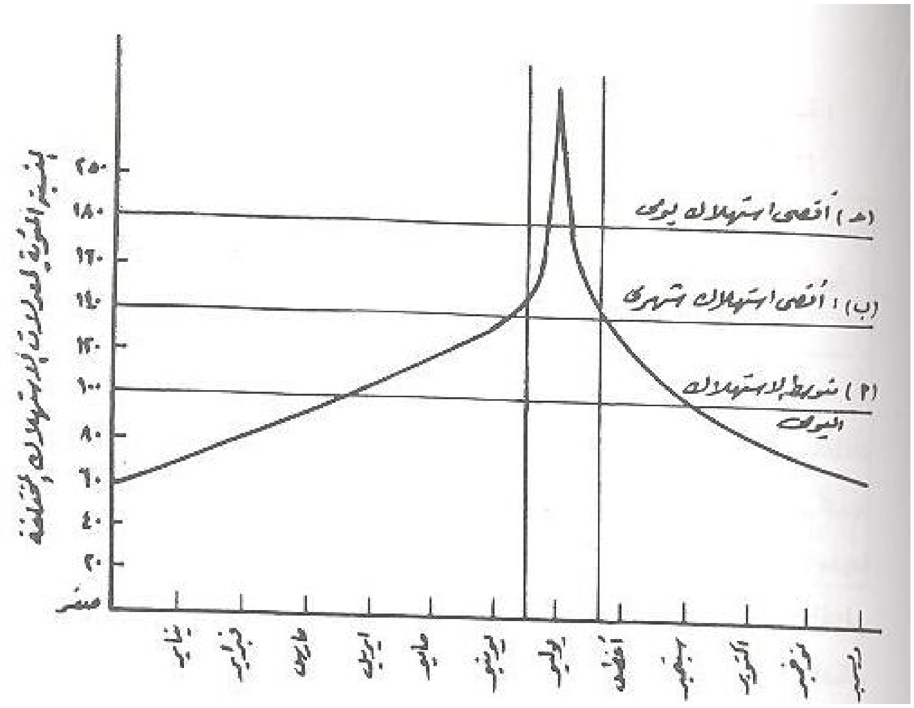


Figure no (1-2) relation between different rates of consumption

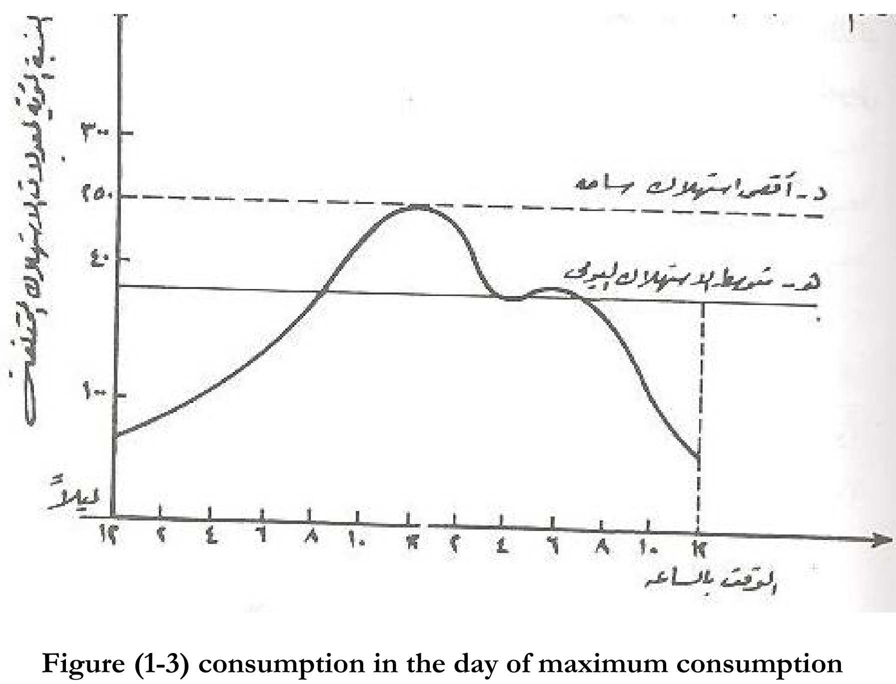


Figure (1-3) consumption in the day of maximum consumption

In case the percentage of population increase is known, the following equation can apply:

(6) Percent increase= $[(1+r)^{n}-1]\times 100$

Where as:

r: refers to the increase factor of annual consumption, 1/10 is deducted from the percentage of annual increase of population.

N: is the project time (years during which the project is performed)

According to the studies conducted for the cities of Cairo, Alexandria, Port Said and some upper and northern governorates and new cities like (Obour- 6th October, the average of daily consumption is determined for different regions within the republic concerning either new cities or governorate capitals, precincts, countryside. The average of daily consumption represents the domestic consumption, in addition to consumption for general purposes, consumption of public buildings, and micro industries. Concerning network losses it ranges between 20-40 liter individual per day. This quantity is included among the average of daily consumption. The lost amount must be deducted when calculating other consumption rates. Table (1-1) shows the daily consumption as well as the loss amount within the network.

Table (1-1) Average of Daily Consumption and losses within the network

Usage	Average of daily consumption Liter/ per capita /day	Losses within water network Liter/individual/day	Average of total consumption Liter/individual/day
1-Capitals of governorates	180	(20-40)	(200-220)
2- Precincts	150	(15-30)	(165-180)
3- Villages up to 50,0 population	125	(10-25)	(135-150)
4- New Cities	280	(0-20)	(280-300)

The following example demonstrates the method of calculating consumption rates of a new city:

Average of daily consumption table (1-2) = 28 3 Liter/Per Capita/ Day

= 28 0 2 Liter/Per Capita/ Day

Losses within the network: 2 Liter/Per Capita/ Day

Maximum Monthly consumption: 1,4 × 28+2= 412 Liter/Per Capita/ Day

Maximum Daily consumption: 1,8 × 28+2= 524 Liter/ Per Capita/ Day

Maximum Hourly consumption: 2,5 × 28+2= 72 Liter/ Per Capita/ Day

Concerning industrial usage, and according to the studies conducted for Cairo, Alexandria, Port Said and some upper and northern governorates and new cities, the rates of industrial consumption is determined, and table (1-2) demonstrates these rates:

Table (1-2) Industrial Consumption Rates

(Liter/Hectar/Second)

Usage	Industrial consumption (Liter/Hectar/Second)
1-Capitals of Governorates (cities)	2
2- Precincts	2
3- Villages up to 50,0 population	2
4- New Cities	3

Concerning hotels, Public buildings, Governmental buildings- hospitals and schools, the average of daily consumption is calculated according to table (1-3).

Table (1-3) average of daily consumption of public buildings,

Hospitals, Hotels and Schools

Usage	Average Consumption
1- Public Buildings- Offices- Schools	50-150 Liter/Capita/Day
2- Hospitals	500-1000 Liter/Capita/Day
3- Hotels	180-500 Liter/Capita/Day

Concerning fire actions, it will be as the following table (1-4)

Table (1-4) Fire actions regarding Population (Liter/S)

Population (Capita)	Firs Action (Liter/S)
1- up to 10,000	20
2- up to 25,000	25
3- up to 50,000	30
4- up to 100,000	40
5- More than 200,000	50

Concerning rural compounds that depends on poultry and animal production, the consumption rates stated in table (1-5) shall be considered

Table (1-5) average of water consumption for animal production

Animal production factors	Average of consumption (Liter/Day)
Dairy Cattle	80-140 Liter/Capita /Day
Meat Cattle	60-80 Liter/Capita/Day
Sheep& Goat	5-8 Liter/Capita/Day
Horses& Mule& Donkeys & Camels	30-40 Liter/Capita/Day
Egg Poultry	35 Liter /100 Chicken /Day
Meat Poultry	25 Liter /100 Chicken /Day
Turkey Poultry	80 Liter /100 Chicken /Day
Goose and ducks	80 Liter /100 Chicken /Day

3- Design Periods

3-1 Design period for hydraulic works

Design period for treatment station is divided to phases that range between 15-20 years and it is related to its design discharges.

3-2 Design period for mechanical and electrical works

Design period for mechanical and electrical works is related to hydraulic design periods and expected lifetime for the equipment that ranges between 15-20 years.

3-3 Design period for civil works

This period ranges between 50-60 years and its implementation depends on the design hydraulic periods of the station.

4- Design discharges

Unit	Design discharge and design basis
1- intake	Maximum monthly discharge+ %10
2- Raw water pump storehouse	Maximum monthly discharge+ %10+ %50 additional units
3- treated water pumps storehouse	Maximum daily discharge +% 50 additional units
4-Distribution Shaft	Maximum monthly discharge+ 1/
5- Flocculating Tanks	Maximum monthly discharge+ 1/
6- Sedimentation Tanks	Maximum monthly discharge+ 1/
7- Filters	Maximum monthly discharge+ 7/
8- Ground Reservoirs	Ground storage is the biggest amongst the following - (variance between the maximum daily consumption and maximum monthly consumption)+ 5/4 of water quantity required for fire fighting. - %15- %40 of the daily production of the station +5/4 of water quantity required for fire fighting. Storage increases in micro production stations.

Unit	Design discharge and design basis
9- Upper Reservoirs	- Time required for chlorine reaction (Hydrochloric acid with bacteria) = 30 minutes +5/4 of water quantity required for fire fighting. Volume of upper storage is as follows: - As for small cities in which high-pressure pumps cease, volume is calculated equal to the cessation period, i.e. (8-12 hours). - In big cities i.e. between 100 thousand and half million population, the capacity of the tank is calculated equally among two or four hours of the city consumption in inverse proportion to the population. - It is recommended to draw a curve of total consumption within the same day, then ad %20 of fire demands to upper reservoirs.

5- Water Resources

5-1 Introduction

Salt water in seas and oceans covers about %75 of the planet. Water evaporates and forms clouds then it return as rains that falls on different areas in the planet with different density according to the difference of pressure distribution areas, wind direction and temperature. Part of these rains evaporates while the other part infiltrate within the ground forming ground water.

The biggest part of the rains flow down to the surface of the earth in water ducts due to water flow and nature of earth layers. These water ducts flow its surplus discharge into seas and oceans to go through the same cycle. This is known as water Hydrological cycle.

5-2 Potable Water Sources

Potable water for supplying cities and other residential compounds can de divided as follows:

- Rainwater
- Surface Water
- Ground Water
- Salt Water

5-2-1 Rainwater

Rainfall rates in Egypt ranges between 2,29mm/year. It is regarded a limited quantity when taking the frequency of rainstorm into consideration. Therefore, it would be uneconomic to benefit from rainwater for drinking purposes for cities and residential compounds because of the expensive cost of assembling and storage works for using it. In Egypt, it is only benefited from rainwater in irrigation purposes for seasonal plantation in some regions. It can be benefited from Rainwater in supplying potable water when there is no other alternative source, provided conducting the following studies:

- Collect data from concerned authorities on rainfall rates and frequency of rainstorm for previous period reaches to 10 years.

- Conduct soil researches for water holding area in order to calculate infiltration rates.

- Leveling and planning the catchments areas of rainwater in order to hold the required quantities of water.

- Locate the course and design transferring lines of collected water to storage tanks.

- Determine the volume of water storage tanks required for saving water supplies during the year taking into consideration sea rates.

- Determine the course and design of water transfer lines to treatment station.

5-2-2 Surface Water

Includes Nile River and its branches, main and secondary canals and conduits. It also includes high dam lake.

Surface water is characterized by its availability in some areas and this makes it the main source of water in cities and residential compounds. However, this water is rarely found potable in nature without treatment due to particles of viscid substances like mud, silt, weeds, solutes, and many bacteria, besides that, surface water source is exposed to contamination and this must be taken into consideration when determining intake site and treatment method.

Contamination sources of surface water includes the following:

- Sanitary drainage water of some cities.
- Agriculture drainage water.
- Liquid wastes from some factories
- Wastes of vessels and residential buoys.
- Human behaviors.

Thus, the following must be assured before selecting water supply source:

- Water quality around the year and contamination sources.
- Availability of water around the year provided that the canal is not subject to rotations.

5-2-3 Ground Water:

Ground water exists under ground inside geological formations with properties that allows water carrying and storage that is known as ground reservoirs.

Ground reservoirs in the Arab Republic of Egypt is divided into three main types:

Sedimentary reservoir in Nile valley and Delta where ground water is located in layers close to the ground surface and feeds on the surplus irrigation water infiltrated from canals. Due to various activities in these area, shallow layers of water is likely exposed to contamination, therefore, it is recommended to establish wells not less than 40 meters depth in order to attain non – contaminated ground water.

- Sand dunes at north coast: it is considered weak reservoirs in terms of its thickness and the existence of seawater under beneath. It is mainly fed on rainwater and it can be pulled with low rates by shallow wells provided not contaminating the well with salt water.

- Nubian Sand Stone: is regional reservoir extends out Egypt boarders. The ground water it includes is old and mostly located at big depths. It is regarded non-renewable within Egypt. Lime stone layers occur north. Ground water can be obtained from Nubian sand stone by digging profound wells reaches to aquifers. Thus, water can flow under pressure without using pumps (Maritime Oasis) or by submersible pumps.

Whereas eastern desert feeds rainfall on the eastern mountains along the red sea which is infiltrated to the ground layers. It is the main source of ground water in eastern desert. Generally, ground water can be supplied either by drill wells or by its flow as springs due to cracks (Splits) in the surface of ground.

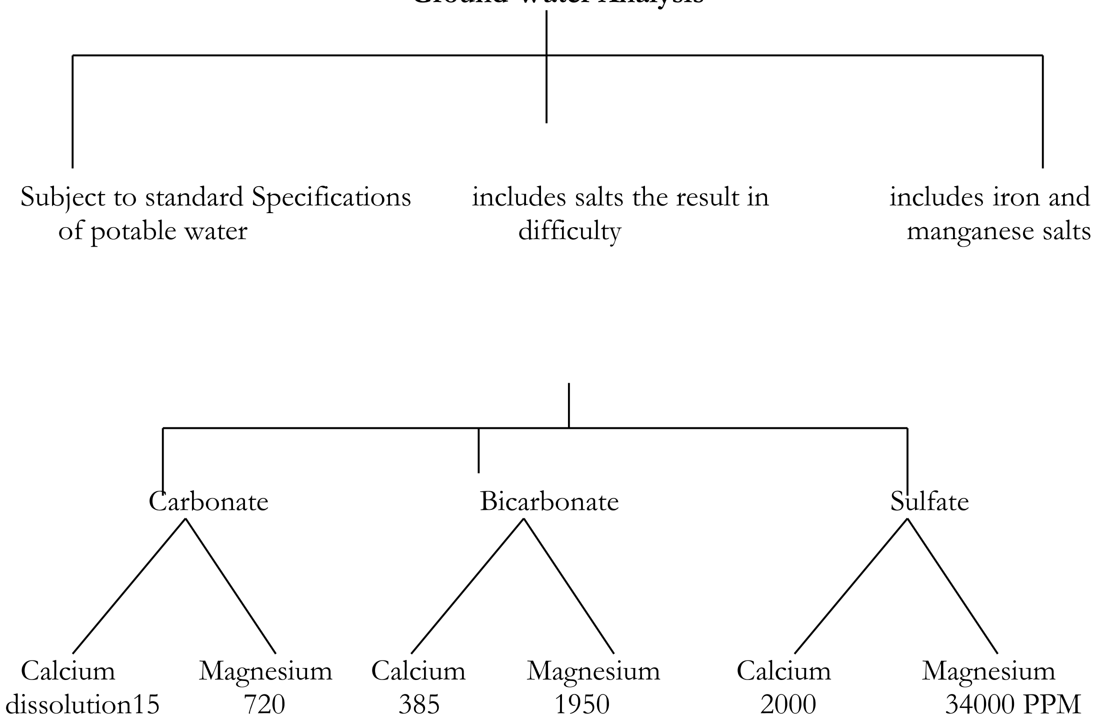
In order to use ground water as a source of potable water, it is required to:

- Test the sites that have potable and uncontaminated water.
- Draw with limited rates to ensure the continuity of water with the required quantity and quality.
- Determine the distance that avoids interventions with conic drawing circles.
- Determine water properties physically, chemically and bacteriologically in order to select and determine proper treatment methods and techniques.
- Refer to design data and studies prepared by ground water research institute at ministry of public works and water resources

5-2-3-1 treatment of ground water

Groundwater is treated if it contains components that prevent its direct use. In this case, treatment technique depends on the quality and quantity of salts it contains according to the following illustration:

Ground Water Analysis



<u>**Note:**</u>

* Hardness resulted from Carbonates or Bicarbonate is called temporary hardness and can be removed by heating.

* Hardness resulted from Sulfates is called permanent hardness.

Treatment method

Transfer all salts chemically to calcium carbonate that has limited dissolution is water. It is sedimented and infiltrated to get rid of deposit. Sedimentation is performed by using one of the following methods:-

A- Using lime only if Bicarbonates salts is available.

B- Using Sodium carbonates if Calcium sulfate salts are available.

5-2-3-2 Ground Water Wells

Safe productions of the well is determined without affecting the level of ground water or the quality and properties of water generated by drilling experimental wells with proper depths and diameters that will be stated later when discussing the elements and design criteria of wells and determine its safe flows.

A- Well Components

It consists of main elements according to the illustrated sketch in figure (1-4).

1- **Well Head:** it is the location above the opening of the well, constructed around it a room of suitable dimensions for placing the equipments of the discharge well; it includes electrical panel for operating the pump complete with all cables, switches, electrical safeguards, valves, discharge and pressure gauges and etc.

2- **Upper Casing**: well pump is installed inside it- it consists of an iron pipe of diameter fit with the pipe to be installed and it must be solid. Its length is determined according to the expected depth of water in the well when pull out of the well. This pipe is coated from outside to a depth not less than 2,5 meter and thickness not less than 5 cm to 30 cm including the mortar above a base of rough sand

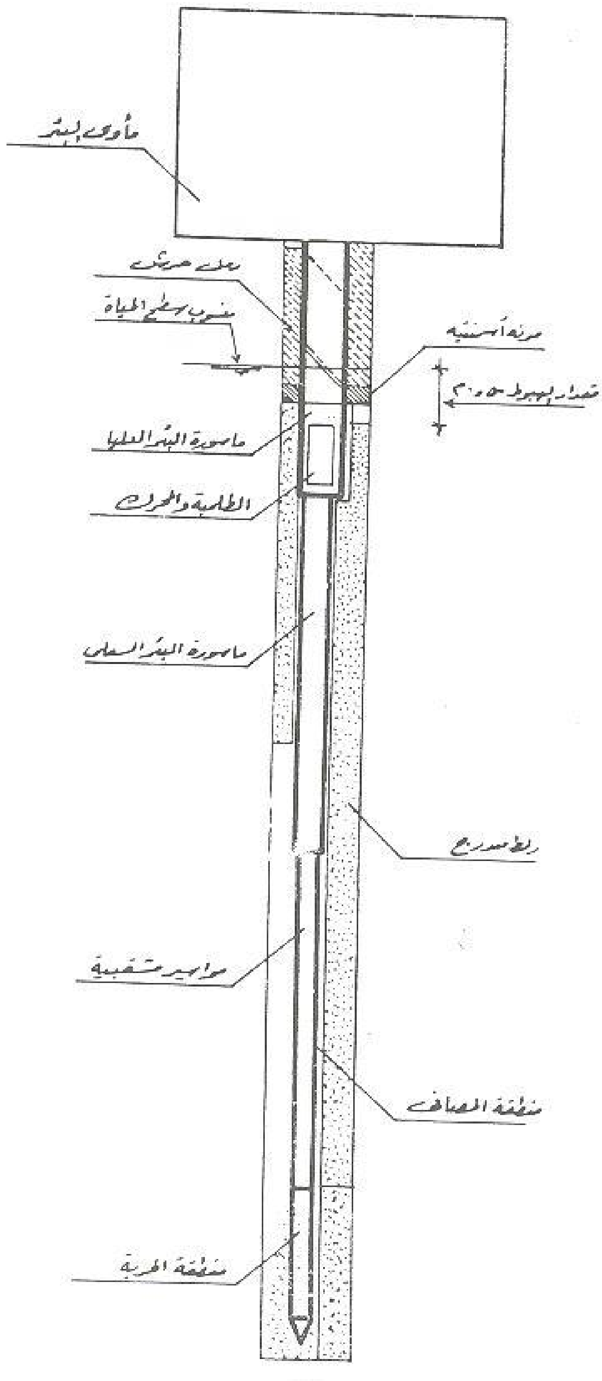


Figure (1-4) statement of well components

Of 1 to 3 mm and with height not less than 20 cm. the rest of pipe length is surrounded by graded gravel of 3 to 16 mm.

3- **Lower casing**: it consists of iron without clips or screens with diameter less than the upper casing by 8-12 cm and surrounded by graded gravel like mentioned before. The height of this casing is determined according to the well design and level of ground water.

4- **Screens**: is the part of the well casing with the same diameter of the lower casing. It contains bores to allow pulling out of water from surrounding soil the well. An additional grid can be installed and its height and number of bores is determined based on the design and hydrological studies of the area.

5- Lance: it is a pointed pipe in the shape of a lance. Sand infiltrated with water is deposited at the end of this pipe and its length must not less than 3 meters.

B- Method of well drilling:

Discharge wells in Egypt are established by using one of the following methods:-

1- Manual Drilling

Using an iron auger placed manually inside the ground layers without using any equipments or mechanical machines. It is suitable for sand soils or clay soils. It issued in cases of small and middle diameters up to 60 meter depth and with diameter not more than 250 mm. caisson or drilling Fluid or Bentonite may be used to facilitate drilling and prevent the collapse of foil surrounding the well.

- After the completion of drilling, pipes are placed and coating layers and protection according to the design data. After that, well is washed and purified to remove drilling fluids and the like from walls that are resulted due to construction.

2- Mechanical Drilling:

This method is performed by using mechanical equipments in drilling operations by installing special pipes by drilling where special digger consist of bevel gears is installed at the end of these pipes. The quality of its materials and solidity is determined based on the soil to be drilled. Drilling residues is pulled out by using pumps inside drilling pipes as well as using Bentonite or some other necessary chemicals. This method is used for all types of soil, diameters and depths. After drilling, pipes are lowered for washing, purifying, and the necessary coatings and protection is placed according to the design of the well.

Treatment methods for removing Iron and Manganese salts

A) In Case of Iron Only

Ventilation is made by using fountain or waterfall of 3 to 4 phases provided that the retention period is not less than 10 minutes, as natural oxidization is made by interaction between water and ambient air and thus, iron salts is oxidized and settled.

If the iron rate is not more than 1,5 PPM, quick sand filtration is sufficient after ventilation.

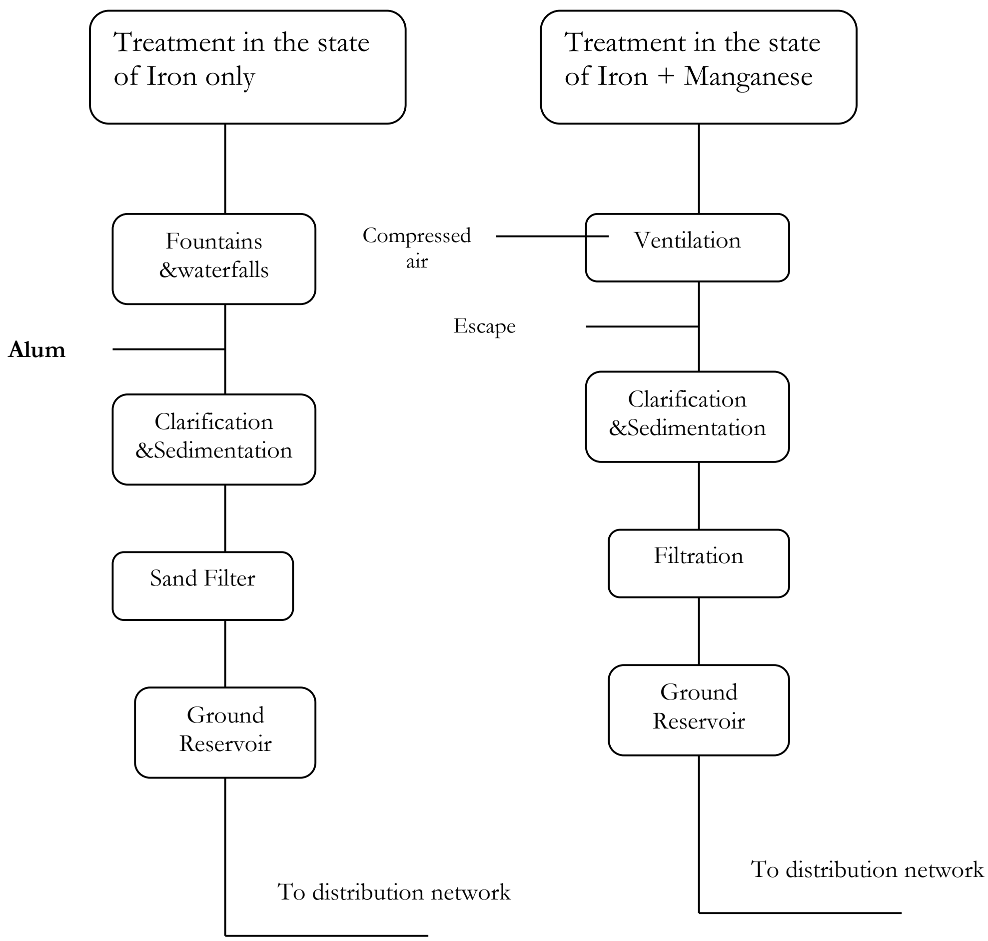
If the rate is more than 1,5 PPM, it is required to execute clarification and filtration processes and add alum if necessary.

B) in case of Iron & Manganese together:

Ventilation is made by using air compressors that push the air from the bottom of tanks that are established for this purpose. Perforated pipe network or porous plates are installed at the bottom.

If total rate is about 1,5 PPM, then filtration is sufficient after ventilation. If the rate is more than this, clarification process is to be done after filtration.

The depth of ventilation tank is three meter and retention period ranges between 10-30 minutes.



C) Using lime + sodium carbonate when salts of magnesium sulfate are available.

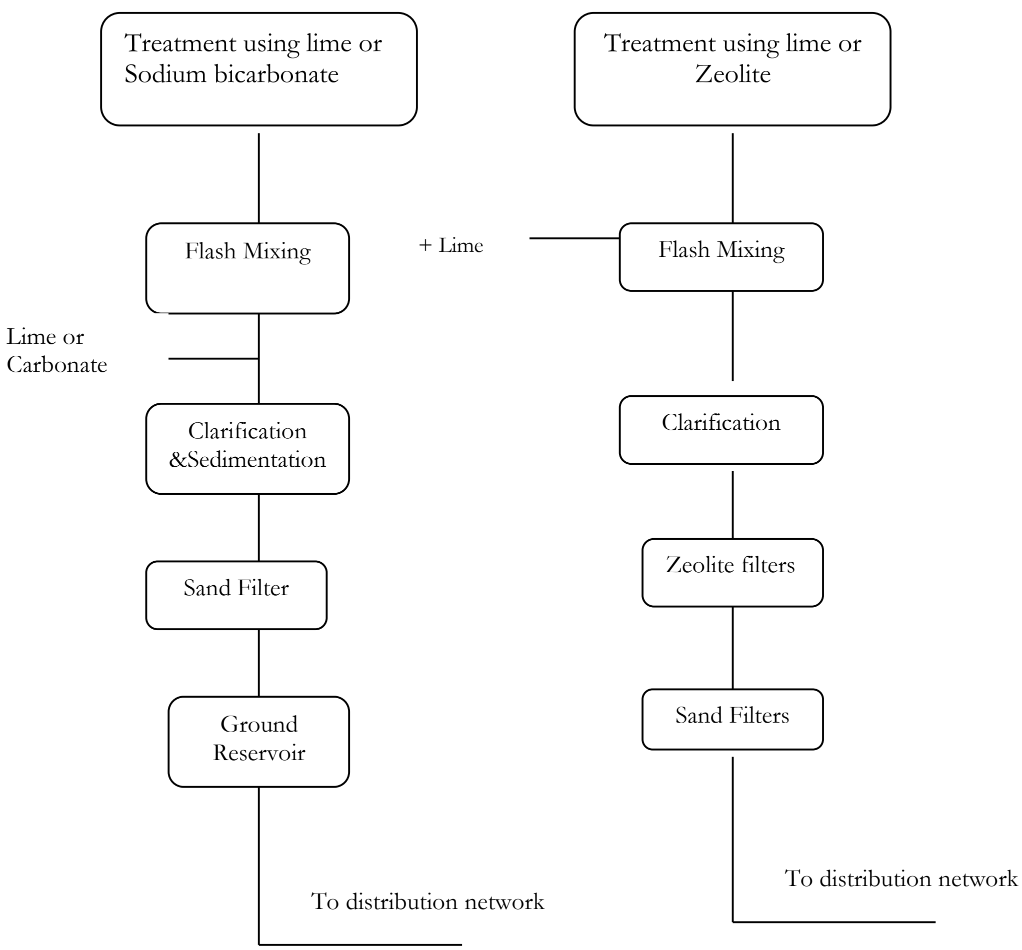
D) By using ion exchange method

E) By using Reverse Osmosis or Evaporation.

Methods A, B, or C is applied to cases of very water hardness. Water quality in terms of hardness rate is determined as follows:

Water type	Hardness rate
Salts Less Than 50 PPM	Soft Water
Salts 50-150	Medium Hard Water
Salts 150-300	Hard Water
Salts 300 Up	Very Hard Water

The following is treatment steps:



5-2-4 Salt water

Most coastal cities that are away from fresh water sources and small tourism compounds in these areas, depends on the desalination of sea, oceans and salt lakes water to use it in supplying these areas with its demands of fresh water. The costs of setting up and operating and maintaining different desalination stations are very expensive compared to the cost of surface water treatment. Therefore, technical and economic comparison study is to be conducted between boring wells near coasts to pull out water for desalination or to pull out water directly from sea for initial treatment before desalination, and between transfer surface water for treatment.

6- Water Properties

Water must be available for humane consumption and ensure safety and health of consumers according to the specifications and standards set by the ministry of health that must be available in potable water as per the following tables:

6-1 Natural Properties:

Property	Maximum limit
Color	20-3 Maximum Limit by Pt/Co scale (Platinum-Cobalt Scale)
Taste	Accepted
Odor	None
Turbidity	5 Jackson units or its equivalent of treated water 1 Jackson unit or its equivalent of ground water and mixture.
(PH)	6,5 9,2

6-2 Non- organic substances affecting the agreeability and domestic uses.

Property	Maximum limit
Desolved salts at 12^{O} C	12 mg/liter
Ferrum (Fe)	0,3 mg/liter of treated water 1,0 mg/liter of ground water and mixture
Manganese (Mn)	0,1 mg/liter of treated water 0,5 mg/liter of ground water and mixture
Copper (Cu)	1,0 mg/liter
Zinc (Zn)	5,0 mg/liter
As CaCo3	500 mg/liter
Calcium (Ca)	200 mg/liter

Property	Maximum limit
Magnesium (Mg)	150 mg/liter
Sulfate (SO_4)	400 mg/liter
Chlorides (CI)	500 mg/liter
Sodium (Na)	200 mg/liter
Aluminum (Al)	0,2 mg/liter
Calcocarbonic Balance.	$\pm$ 0,1

6-3 Chemical Substances that affects public health

6-3-1 Non-Organic substances

Property	Maximum limit
Lead (Pb)	0,05 mg/ Liter
Arsenic (As)	0,05 mg/ Liter
Cyanide (Cn)	0,05 mg/ Liter
Cadmium (Cd)	0,005 mg/ Liter
Selenium (Se)	0,01mg/ Liter
Hydrargyrum (Hg)	0,001 mg/ Liter
Chromium (Cr)	0,05 mg/ Liter
Nitrate As (N)	10 mg/ Liter
Nitrite As (N)	0,005 mg/ Liter
Fluorides	0,8 mg/ Liter

6-3-2 Organic Substances

(1) Pesticides

Property	Maximum limit (mg/liter)
Chlorine	20
Aldicarb	10
Aldrin/ dialdrin	0,03
Atrazine	2
Bentazon	30
Carbofuran	5
Chlordane	0,2
Chlortofuron	3
D.D.T	2
1,2 Dibromo chloropropane	1
2,4 D	3
1,2 Dichloropropane	2
1,3 Dichloropropane	2
Hexachlorobenzene	1
Isoproturon	9
Lindane	2
MCPA	2
(Chlorophenoxy)	
Methoxychlor	2
Metolachlor	1
Molinate	6
Pentachlorophenol	2
Pentaclioroifenol	9
Permerthrin	20
Propanil	20
Simazine	2
Trifluralin	20

Chlorophenoxy herbicides other than 2,4 dand MCPA

2,4 DB	90
Dichloroprop	100
Fenoprop	9
Mecprop	10
2,4,5 T	9

(2) Other Organic substances

Tributalyltin Oxide	2
Phenol	2

Disinfectants and disinfectants byproducts

Monochloramine	3
Di and trichlormine	5
Bromate	25
Chlorite	20
2.4.6 Trichlorophonal	200
Trihalomethanes	100

Chlorinated Acetic Acids

Dichloro acetie acid	50
Trichloro acetie acid	100
Trichloro acetaldhyde	10

Halogenated acetonitriles

Dichloro acetonitrile	90
Dibromo acetonitrile	100
Trichloro acetonitrile	1
Cyanogen Chloride	70

Chlorinated Alkanes

Carbon tetrachloride	2
Dichloromethane	20
1,2 Dichloroethane	30
1,1,1 tricloroethiane	200

Chlorinated Ethanes

Vinyl chloride	5
1,1 dichloroethane	30
1,2 dichloroethane	50
Trichloroethane	70
Trichloroethane	40
Total Hydrocarbons as Toluene)	100
Benzene	10
Benzo (a) pyrine	0,7

Chlorinated Benzenes

Monochiorobenzene	300
1.2 Dichlorobenzene	1000
1.4 Dichlorobenzene	300
Triclorobenzene	20
Di(2- Ethlyl hexyl) adipate	80
Di(2- Ethlyl hexyl) phthale	8
Acrylamide	0,5
Epichlorohydrin	0,4
Hexachlorohybutadiene	0,6
Edetic acid (EDTA)	2
Nitrilotriacetie	2

6-4 Microbiological Standards

6-4-1 Total Bacteria Count

By Poured plate method

(1) at 37 C for 24 hours, not more than 5 cells /1cm^3

(2) at 22 C for 48 hours, not more than 50 cells /1cm^3

6-4-2 pollution indicators

(1) Total coliform count: %95 of the samples tested during the year must be clear completely from coliform in 100 cm^3 of the sample.

No sample shall contain more than 3 cell/100 cm^3. Two sample of the same source shall not contain any bacteria cell.

(2) Bacelli

All samples must be clear from Baceelli

(3) Faecal Streptococci Enterococci

All samples must be clear from Streptococci Faecal Enterococci

6-4-3 Biological Test

When testing water microscopically, it must be completely clear from Protozoa and all kinds of worms causing diseases and blue-green algae.

6-5 Radioactive Substances

Derivatives from Alpha (a) 0,1 micro- curie/liter

Derivatives from Beta (B) 1,0 micro- curie/liter

7- Treatment Processes

7-1 Flocculation and Sedimentation Processes

It is made in either separate clarifiers or clariflocculators

7-1-1 Flocculation

It is rectangular tanks supplied with horizontal and vertical mechanical flippers mechanical equipments can also be dispensed with and supplies it with vertical barriers that allow the zigzag movement of water.

7-1-2 Sedimentation (clarifiers)

It is either rectangular or circ ular tanks.

7-1-3 Clariflocculators

A- Traditional method

In this method, flocculation is made in the middle of the tank. Water comes out of the tank to sedimentation area by Weirs. Such tanks are circular.

B- Clarifiers of high speed sedimentation, and there are two types:

1- Solid Contact

It is usually made by forming viscous layer spreading in the bottom of the tank. Water comes out from this layer retaining particles inside this layer such as pulsator or accelerator lamella plates or tube settlers.

2- Barriers, plates or bent pipes

In this method, barriers or network of bent plates is installed. Water direction is from bottom to the top where deposits are settled at the bent surfaces, which improves the efficiency of sedimentation processes. This method is applied in compact units.

C- Flocculation by Flotation:-

It is made by mixing air with water to float floccus and get ride of it from the surface.

7-2 Coagulation Processes

It is made by adding chemical substance to water to interact with the alkalinity of the water. This generates what is knows as floccus that attracts particles at its surface and therefore, its size increases and this accelerates its sedimentation. Coagulation is made as follows:

1- Adding Coagulant (Alum)

This is performed using pumps or special injectors with controllable flows.

Alum dosage is determined according to the type of raw water and temperature. The required dosage must be specified by the laboratory.

2- Flash Mixing

It aims at distributing, spreading or mixing coagulant with water rapidly and completely. This is made by injecting alum liquid in the entrance pipe or adding it to special flash mixing tanks.

3- Slow Stirring

It aims to give sufficient time to complete chemical interaction in order to allow the floccus to attract particles at its surface and settle it later. This is made in special tanks supplied with mechanical flippers with slow speed or by using barriers method.

7-3 Sedimentation:

It seeks to settle much floccus formed in flocculation processes and get rid of deposits by using special drainage system according to the type of the designed tank and factors affecting efficiency of sedimentation:-

1- Retention Period
2- Over flow rate
3- Water level in the tank.
4- Added chemical dosage from alum and chlorine.
5- Water properties.
6- Deposits.
7- Tank capacity and availability of air currents.
8- Sludge collection and drainage system.
9- Water exit and entrance system

7-4 Filtration process:

Water from sedimentation process goes through filters where all deposits are retained and thus improving chemical properties. Filtration processes are performed through many phases:-

1- Retain some deposits in the surface gel layer formed in the first half hour after the filter is washed. (Schmutzdecke).

2- Settle deposits in sands due to its gravitation by electric charges.
3- Biological Interactions for minute creatures living in water. (Biological Filtration).

7- 4-1 Filters Type

1- Slow sand filters.

Filtration rates of these filters are low compared to other types.

2- Quick sand filter.

- Gravity Filters.
- Pressure Filters.

7-4-2 Filtration periods

Period during which filter works directly after being washed until it is washed again depends on many factors including:

1- Filtration rate.
2- Quality of Filtered water in the filter.
3- Filtration cleaning rate.

When head loss reaches its maximum value permitted, filter need to be washed to remove settled deposits whether in pores or in surface. Washing is performed according to many programs and tests using one of the following methods of quick sand filters:-

A- Using water only on two stages with low flow then high flow.
B- Using water with compressed air by using air only, then air and water, then water only.

C- Using flipping hands and then use washing water. Washing shall be made from the bottom until the top (unlike the filtration process).

D- Using surface washing methods to reduce loss of filtered water used in washing.

Concerning slow sand filters, filters are cleaned by scrapping the surface layers at 5 cm depth manually or mechanically. Sands are compensated at times.

7-4-3 under Drainage System

It is located in the bottom of filter under filter media. It is divided into two types:

1- Nozzle System

Where concrete slabs are installed over special holders under filter media, on which nozzles are installed with clips or holes, which are 0, 2 mm smaller than sand grains, on the lower surface where filtered water is collected after being transit on sands in a tank below these slabs.

2- Nozzleless System:

It consists of secondary punctured pipes made of P.E or PVC. These pipes discharge in main assembly line outside the filter or in concrete blocks.

7-4-4 Filter media

It is sand and it must be graded as per the sizes of specific coefficient as well as effective diameter according to the selected design for filtration flows. When determining the thickness of filtration media must take into consideration the expansion ratio that occurs in sand during washing process.

7-4-5 Wash water drainage system

Air and water pressure in drainage system of wash water and its upper channels shall be suitable in order to prevent the filter media to come out with washing water to the sludge.

8- Survey Works

Survey works are important factors on which design and distribution of project units are based. It is important for the distribution of suitable places for these units and the optimum use for economizing the used energy, whether for water sources to be treated or discharge its wastes or periodic transition between treatment units, or push water to distribution network for consumers. Required Survey works are summarized in the following particulars:-

1- Determine the main four directions for the site.
2- Budget network of the site at distances determined according to the nature of land.

- It shall not exceeds 50 meters maximum in two directions and proportionate to the nearest fixed point whether a lock or a bridge in the water passage or any bench mark.

3- Survey main landscapes surrounding the site such as the roads, drains, canals…etc.
4- Specify benchmarks in suitable places inside the site and mark it to refer to it.

9- Soil Studies

Components of soil studies:

- Study general layout of the site for treatment works in order to determine the location and depth of sensors.
- Study hydraulic sector of treatment units to determine depth of required sensors based on the loads and depth of structures.
- When taking sensors to sump location it is necessary to determine suitable depth and number.

10- Site Selection

10-1 Introduction:

Selecting suitable site for water treatment station is the most important studies required for designing and establishing the station. Many factors affecting the suitable selection shall be studied in case on the lack of studies or previous general layouts for cities and compounds that requires potable water supply.

10-2 Factors affecting site selection

10-2-1 Source:

It is the location and source of raw water whether from wells, surface water or salt water which are relevant to the selection of station site. The following is a demonstration of these sources.

10-2-2 Wells

When ground water is used as a source of water supply, the Aquifer, water quality and water direction are the main factor for selecting the suitable site for water station. The site is selected in front of the direction of water current to avoid sources of contamination.

In case of boring wells to use ground water as an assisting source for the water volumes required for treatment station, water shall be valid for use according to Health criteria.

10-2-3 Rivers and Fresh Lakes

Rivers and fresh lakes must be away from sources of contamination and to be in sufficient volumes that fulfils the demands around the year.

10-2-4 Seas and Salt Lakes

The source of this water must be away from any potential sources of contamination, with taking into consideration tide and ebb phenomena.

10-3 Area Required:

The required are for any station is determined according to the flow, water quality and the requirements of the units to be constructed whether a well, desalination or treatment station.

10-4 place

10-4-1 When selecting the location of water treatment station, current and future planning for the subject city must be taken into consideration, provided that it shall be:

1- Near the city or the residential compound to be supplied with water.

2- Near the main supply lines existed if any.

10-4-2 Hydraulic Factors:

When selecting the location of the station to suit the natural levels of its location with the hydraulic gradient of the treatment units with its different types, if possible.

10-4-3 selection of location land

It is necessary to study a group of available locations using cadastral contour maps and air photographs, then by conducting on site examination for each available location and evaluate it technically and economically.

If the selected location is owned by the state, allocation procedures must be followed. If the location is owned by the public sector, dispossession procedures must be taken for the public benefit.

10-4-4 Roads:

Roads leading to the station are considered essential factors that should be taken into consideration when selecting and planning the location.

10-4-5 utility

When selecting the location of treatment station, it must include the following:-

1- The ability of transferring raw water from the source to the location.
2- The ability to get rid of filters washing water and surplus water.
3- The location must be near power source.
4- The ability to connect the location to roads and wire and wireless communications.

10-4-6 Soil Borings

10-4-6-1 Establishments

Soil borings affects the comparison between available locations such as:-

10-4-6-1-1 Ground water

The abundance and high level of ground water increase the construction costs.

10-4-6-1-2 Stony Soil

When comparing between available locations, technical and economical studies shall be conducted for boring and construction costs.

10-4-6-1-3 Non- stony soil

It is necessary to study the properties of non-stony soil to determine the construction method or the need to replace the soil and the effect of this on the cost of establishments.

10-4-6-2 Wells Station

Optional wells are performed to determine the geological and hydrological nature of the location as follows:-

1- Ensure that there is an additional ground reservoir valid for use based on the available studies.
2- Penetration method of Soil to reach to the ground reservoir.
3- Determine the flow efficiencies of the well.
4- Determine the safe flow rates of these wells.
5- Determine the circle of influence at different flow rates.

10-5 Environment

When selecting the location of treatment station the following must b observed:

1- Safe distance from different sources of contamination, and from populated areas, taking into consideration the expected future expansions.

2- Expected noise during construction periods and during operation.

3- Air Pollution resulted from the dispersion of chemicals during its delivery or circulation in the station.

4- Effect of the bright night-lights on the residential compounds and the disturbance it causes.

11- General layout of the station

After specifying the treatment method and site selection, general layout of the station is determined according to the required treatment elements that are identified by the laboratory tests and previous experience. The general layout of the station shall include the areas required for operation, control, maintenance and services based on the demands determined by the concerned authority. When preparing the general layout, the following points must be taken into consideration:

1- Location topography, nature of the soil, ground water level, and roads leading to the location.
2- Connecting general layout with the public roads
3- Protecting the location from external effects.
4- Select suitable location for control room of treatment operation units.
5- Handling the difficulties of construction by minimum costs.
6- Determine the additional units required for some treatment phases.
7- Hydraulic balance among the successive treatment units to achieve the minimum losses, and this is helped by the proper planning of the treatment unit of the station.

8- There should be enough spaces between treatment units and other facilities to facilitate installation, operation and maintenance works.

9- Separate sanitary sewer network from the drainage network of filter washing waters and sludge.

10- The ability to discharge and dispose of the unexpected surplus of the station to sludge drainage network.

11- Proper measures must be taken to reduce the risk in the station resulted from using chemical materials.

12- Suitable stores must be provided in the station to store filtration materials, pipes and other equipments.

13- Future expansion must be taken into consideration in addition to the needs resulted from this expansion.

14- Chemicals lines must be reduced to avoid operation problems. This is made by locating chemical supply areas near application area.

15- Design suitable network of internal roads for easy supply and handing of chemicals, and avoid human handling of these materials as possible.

16- Administrative and service buildings must be away from the units causing noise.

17- Power supply units must be near the units of main work in the station.

18- Consider the design of facilities required for the station like water supply networks, fire fighting, irrigation of green lands, drainage, lighting of the site and communications.

19- An external fence must be established around the site including surveillance towers, entrances, security information rooms.

20- Works of Site adornment must be taken into consideration.

12- Protection and control methods

It means the systems set to control the performance and efficiency of water treatment station concerning operation safety, ensure treatment quality, achieve required health standards of potable water and protect it from contamination, and guarantee the optimum management of the station during the lifetime of its various units.

12-1 Control methods:

The main purpose of using control system in potable water treatment station is to regulate some main elements in the station to control the management of different units to ensure the optimum performance under different conditions and by lest possible costs. Such control system is sensitive to any hindrance, cessation or disparity of any course of any main operation. It also helps the operation officer to analyze and study the generated results and therefore, he can work on improving the operation and performance methods and save the costs.

Control system in water stations is manual, half-automatic or automatic according to its easy operation and reliability.

Control components in operating station units depend on the application of machines and equipments, whether mechanical as indicators or controllers or actuators, which are operated by buoys, pulleys and connecting rods and it is rarely used in the present time, or hydraulic as flow regulators of filters that are operated by differential pressure and differential speed, or pneumatic and it is used in many purposes through limited spaces. The most common type currently used is the electronic type, which is used in many equipments and for unlimited spaces.

Control of units operation is made as follows:

12-1-1 Intake

*- Isolating blocks are used to isolate the intake as well as to control the depth of water suction in the shore intake.

*- Isolating gates and manual valves are used to control the isolation of any suction pipe.

12-1-2 Raw water pumping warehouse.

- Indicators of raw water sump and automatic separation machines of pumps are used when the level becomes less than the control limit.
- Manual or electrical suction and discharge valves are used to isolate the pumps in case of emergency or maintenance.
- Water flow meters are used in the main flow lines in order to control water speed and flow rates of clarifiers. It also helps to control the dosage and quantities of added chemicals such as chlorine and alum.

12-1-3 Coagulants

- Manual entrances are used as movable weirs to control the entrance of raw water to coagulants, as well as to adjust the flow rates of coagulants.
- Fixed weirs are used in the coagulants exists to control its hydraulic flows.

12-1-4 Filters

- Buoys are used in the surface of filters to control the consistency of water level above filtration media.

- Meters and regulators of filters water flow are used to control filtration speed and rate.
- Pressure loss meters in filtration media are used to control and determine filter run and to determine the time of filter washing, thus preserve the filters efficiency.

12-1-5 Ground Reservoirs

- Manual gates are used to isolate parts of the reservoir in emergencies and periodic maintenance works.

- Buoy and indicators of level are used to control volumes of water circulated in the station.

12-1-6 Filtered water pumps

*- Indicators of raw water sump and automatic separation machines of pumps are used when the level becomes less than the control limit.

*- Manual or electrical suction and discharge valves are used to isolate the pumps in case of emergency or maintenance.

*- Water flow and pressure meters are used to control water speed- line pressure and volume of generated water.

12-2 Protection methods

The main purpose of using protection methods and systems in treatment stations of potable water is to protect the safety of all facilities, production units and components, individuals and potable water against all external effects and factors and different operation conditions, and to guarantee its continuous performance and production at the optimum efficiency. This is detailed as follows:-

12-2-1 External intake

1- Determine the intake location according to the resolution of the minister of health regarding protecting water station intakes from contamination.

2- Determine raw water suction level from source, provided that it is not less than 50 cm depth to avoid oils, and not exceeds 2 meter to avoid suction from areas including Anaerobic bacteria and water of poor properties that needs big quantities of chemicals such as chlorine and alum to purify it.

3- Install buoys, barrels or barriers in the entrance to prevent oils and floated materials from entering the station.

4- Coarse and fine screens are installed to prevent weeds from entering treatment units.

5- Proper Fences and handrails are used to protect both the intake and individuals.

12-2-2 Clarifiers, filters, ground reservoirs and sumps

*- proper isolation is used for tanks to protect the facilities and water from contamination.

*- connections of surplus water are used for coagulants, filters and ground reservoir to protect it from drowning.

*- fences, handrails and covers are used to protect persons and water from pollutants.

12-2-3 Chemicals & Chlorine.

*- provide mechanical handling methods.

*- Provide ventilation, lighting and balance (disposal) of poisonous gases.

*- Using alarm, warning and safety methods.

*- provide exit (escape) methods for persons in emergencies.

12-2-4 Pumps and distribution pipes.

*- Check valve are used to protect pumps and prevent water return in case of sudden cessation of the engine (power cut for electrical engine).

*- Safeguards are used against water hammer to protect the pump in sudden cessation of the pumps.

*- Air valves are used at high levels of distribution pipes to prevent its explosion when forming big air bubbles.

12-2-5 Electrical Engines and Equipments:

*- Using safeguards against electrical short cut, over current, or voltage drop.

*-Using alarm, warning and caution methods in case of overheat of engines and equipments, lack of oil in the engines to protect it from damage.

12-2-6 Personnel

Provide personal protective equipments for personnel in different fields and follow the instructions of Occupational safety and health in all fields and phases of treatment station. Provide methods of rescue and medication in emergencies.

Chapter 2: Design Rules

1- Hydraulic design

2- Mechanical design

3- Electrical works

4- Architectural and constructive deign

5- Preparing tender documents

1- Hydraulic design

1-1 Intake:

Purpose:

Deliver water from its source whether rivers or canals to treatment station with the required demands.

Components:

Intake types are divided to:

- Pipe intake.
- Shore intake.
- Submerged intake.
- Movable intake.

- **Pipe Intake: (See Figure no. 2-1)**

It consists of two or more pipes extended along the shore to enough distant in the Nile or canal away from the shore. These pipes are borne on metal or reinforced concrete structures.

The following must be observed:-

- The pipe must be at 1,0 m depth from water surface. If the level in the water passage changes, pipes must have more than one opening that are closed according to the level and remain in constant depth from water surface. The intake must also be supplied with the necessary valves and nozzles around the openings.
- Place markers for navigation along the pipes line.
- Place rubber bumpers in the pivot point of pipes over the metal structures.

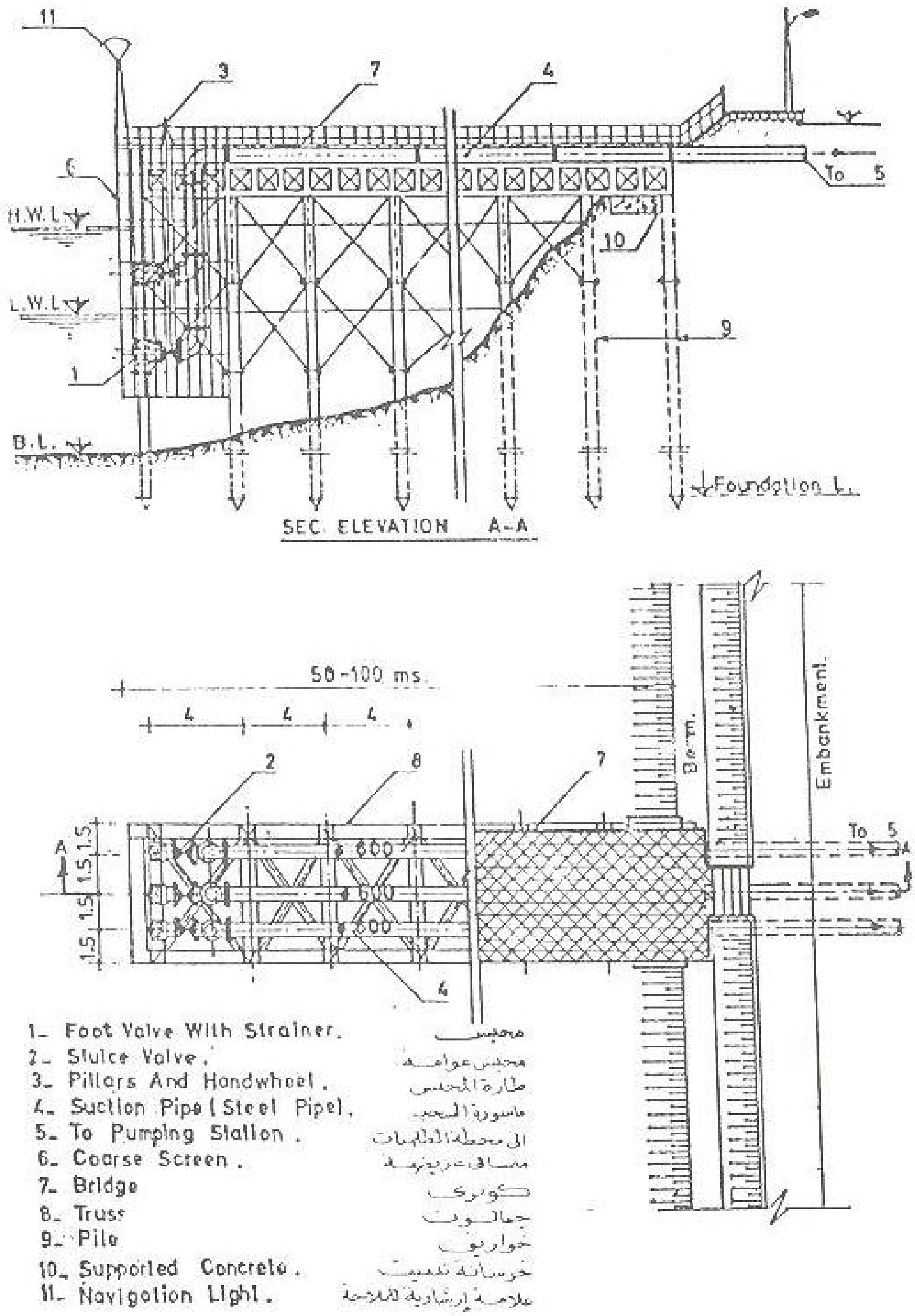


Figure (2-1) Pipe intake

- **Shore intake: (see Figure (2-2) pipe intake)**

It consists of wall or annexes directly built on the shore of water passage from reinforced concrete or brick to prevent the entrances of water pipes that are consisted of one or more pipe. Pipes extend under the bridge of the water passage and ends in raw water piping sump.

The following must be taken into consideration:

- The gradient of the pipe shall not be less than %1 towards pumps warehouse.
- Ensure the straightness of suction pipes.
- Provide the intake with the coarse screens and big objects in the front area of suction area.
- Provide the necessary protection for intake pipe as per the stipulations and technical specifications of pipes line used in the code of potable water and sanitary sewage subject to the ministerial resolutions no. 268/1988, 149/1994, and 283/1994.

- Submerged Intake (See Figure 2-3)

It consists of one or more pipe fixed in the bottom of the water passage by concrete beams or in a small tower.

The following must be taken into consideration:

- The pipe nozzle shall be under water level and higher than the level of water passage, intake pipe shall also be supplied with nozzles.
- Ensure the straightness of suction pipes.
- The gradient shall not be less than %1 towards pumps warehouse.

- Movable Intake (see figure 4-2)

It consists of flexible hose extended in the water passage and born on wooden plates floated in the water surface, or pipes that are installed and released quickly and work by mechanical lever.

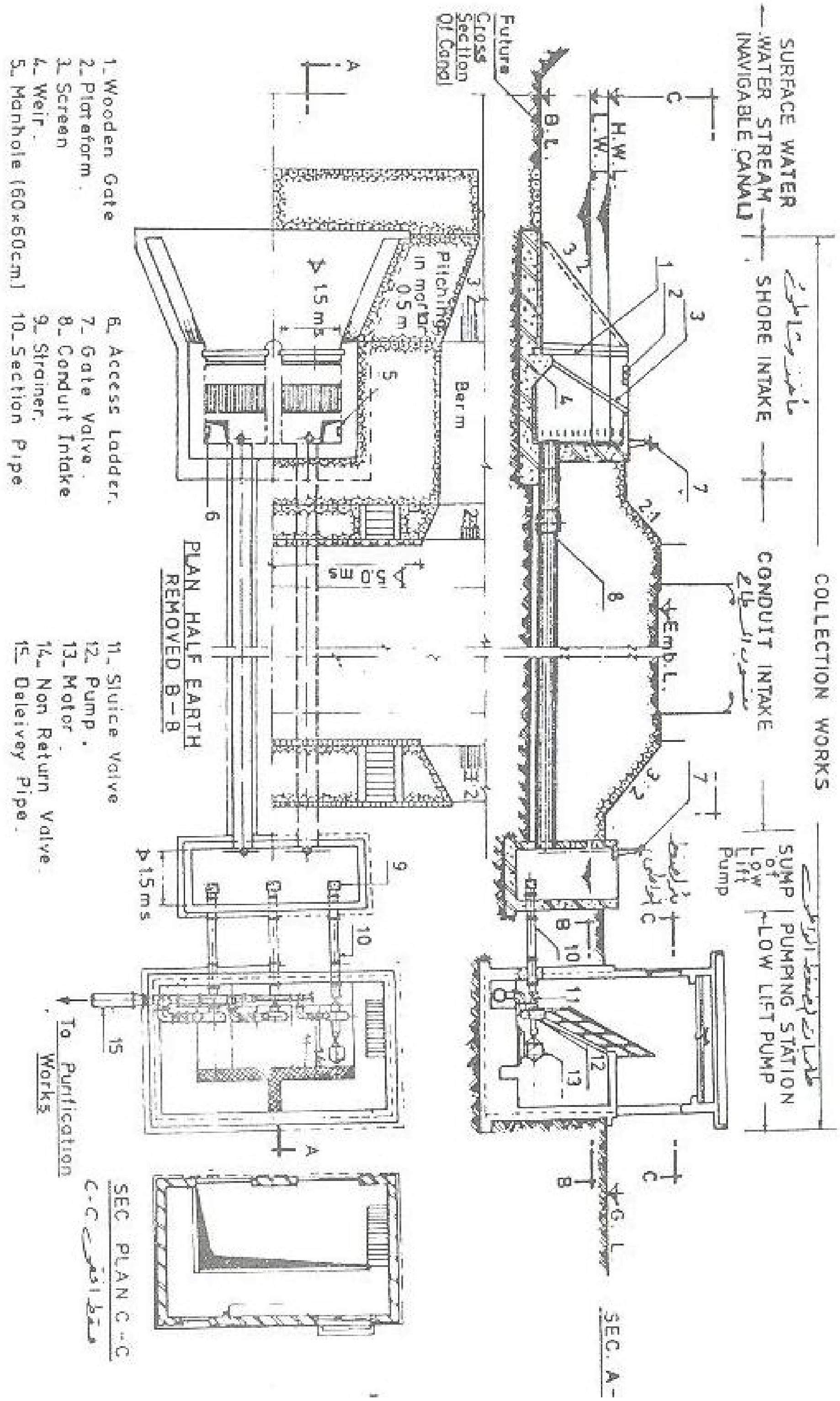


Figure (2-2) Shore Intake

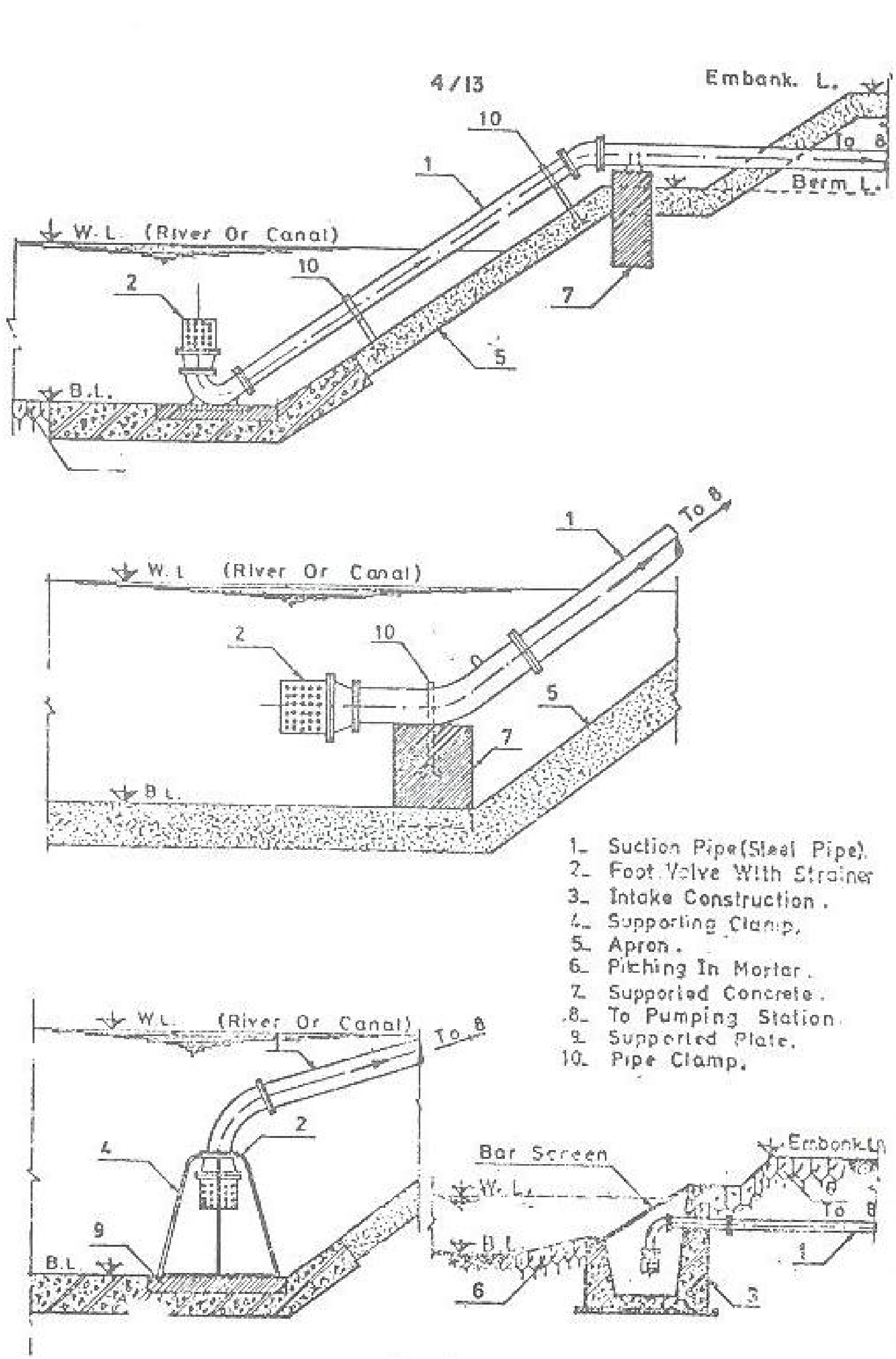


Figure (2-3) Types of Submerged Intake

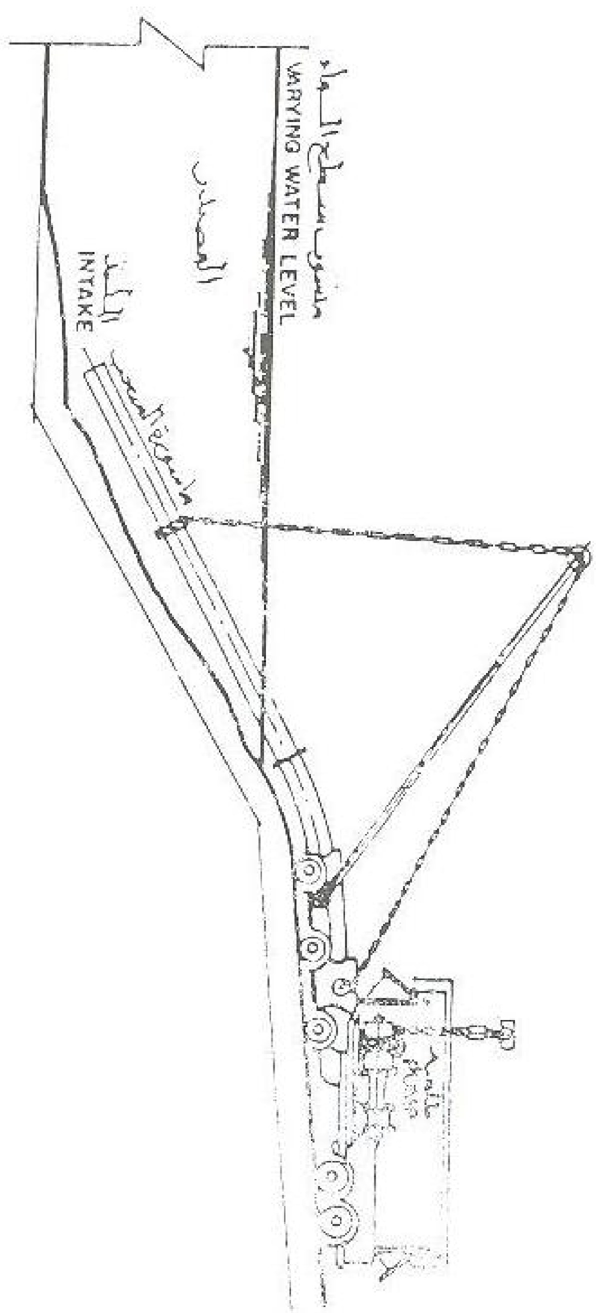


Figure (2-4) Movable intake

Design rules

1- water speed in intake pipes shall not be less than 0,6 m/s and not exceeds 3 m/s

2- calculation of loss:

- Pressure loss due to friction:

(Hazen) William equation is applied

$$H= \frac{6.78\ L}{d.\ 1.165} \left(\frac{V}{C}\right) 1.85$$

V: water speed m/s

d: pipe diameter m

C: Hazen William equation

L: pipe length m

H: pressure loss m

- Pressure loss for elbows and valves

The following equation applies:

$$\mathbf{H= K.\ \frac{V^2}{2g}}$$

K is (loss coefficient) depending on each case.

1-2- Raw water pumping sump:

Purpose:

Receiving incoming water from the intake and pumps takes water from it to transfer it to treatment units.

Components:

It is established from reinforced concrete. It is either rectangular or circular according to the numbers of raw water pumps and soil nature.

Design Rules:

Refer to the mechanical design in this volume.

1-3- Distribution Shaft

Purpose:

Receive water from raw water pumps to distribute it to coagulants or clarifiers.

Components:

It consists of rectangular or circular room made of reinforced concrete. The room is divided from inside to openings equal to the number of pipes inside coagulants or clarifiers by a fixed level weir, taking into consideration the openings required for future expansions. **Figure no (2-5).**

Design rules:

- The diameter shall not exceed 5 meter.
- Water speed inside coagulants supply pipes shall range between 0,5 to 0,9 m/s.

1-4- Flash Mixer

Purpose:

It is used to mix alum solution with raw water. Mixing is made in a tank supplied with mechanical stirring before it enters coagulation tanks, or by injecting alum solution in the discharge pipes of raw water before it enters to the distributor.

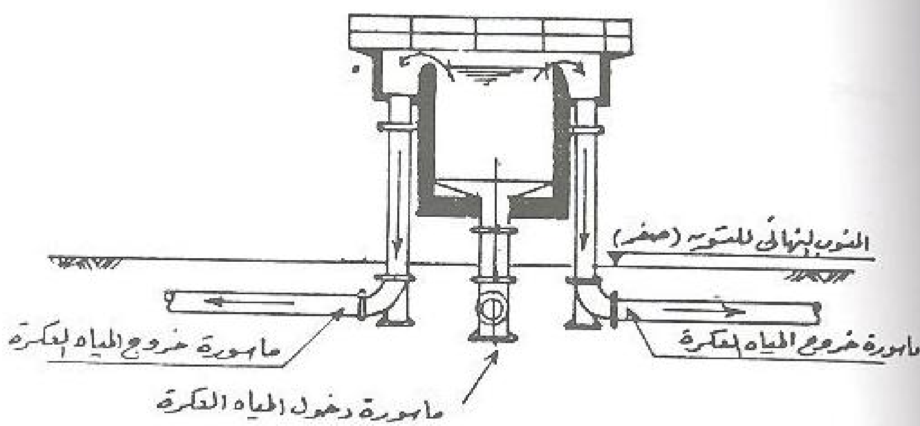


Figure (2-5) Distribution Shaft

Components:

A rectangular or circular tank made of reinforced concrete. Small flapper is installed above this tank to stir alum solution regularly to complete dissolution and mixing. Water is taken from this tank by a weir higher than the weir level of the next coagulation tank with the same specifications of the distributor.

The following must be taken into consideration:

Pipes going out from flash mixing tank shall be of the same diameter and supplied with check valve.

Design Rules:

- Retention period= 1/2 -1 minute
- Power of mixer engine= 2-5 kilo watt.
- flipper speed= 150-200 turn/ minute

1-5 Flocculation and Sedimentation Tanks (in separated way)

First: Flocculator:

Purpose:

Forming floccus as a result of interaction of coagulants with natural or added alkalis. The floccus reticulate and became bigger; therefore it settles in sedimentation tank.

Components:

Tank from reinforced concrete in which stirring is made either:

(A) Hydraulically inside courses made by internal baffles either vertical or horizontal.

(B) Mechanically by using:

- Flippers with vertical or horizontal wheels
- Propeller flipper.
- Turbine flipper
- swinging flippers.

Mechanical flippers are supplied with electrical engines with different speeds to control stirring speed required to form floccus. See figure no (2-6).

Design Rules:

Retention Period: 2- 4 minute.

Water depth in tank: 2-3 meter

Speed between baffles is about 0, 3 m/s.

Distance between walls: 0, 75- 1, 5 m

Peripheral speed in mechanical stirring shall be about 0, 3 m/s.

Tank with mechanical stirring contains three rows of flappers where the net area of the first row is %35 of water area; second row is %25 of water area, and third row is %15 of water area.

Second: Clarifiers

Purpose:

Settle floccus formed in coagulation tanks and the suspended particles in its surface in the tank bottom.

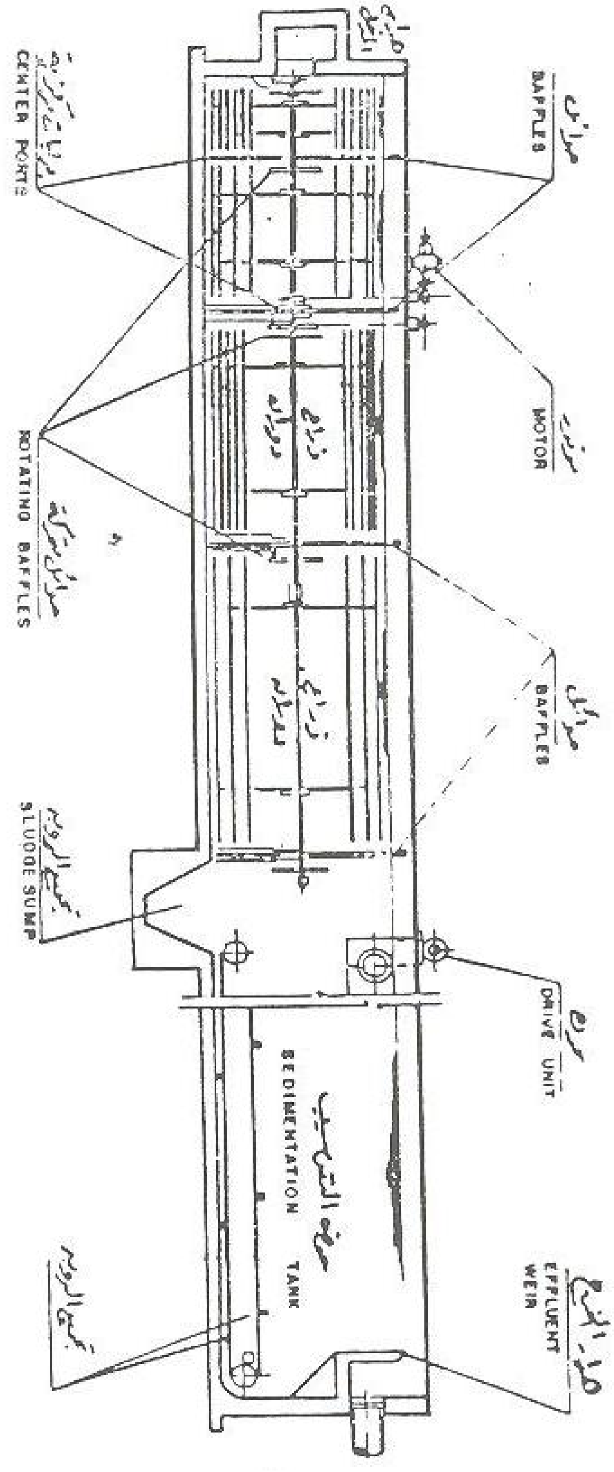


Figure no. (2-6) Flocculation and Sedimentation Tanks (in separated way)

Sedimentation Method:

- **Static Sedimentation :**

It depends on the falling speed of suspended particles is higher than speed of water flow from down to up. This depends on the volume and density of suspended particles. Miles of deposits area in the bottom shall be 45-60 degree to allow sludge flow regularly or by intermittent system. However, change of temperature between incoming water and the water in the tank results in currents that invert sedimentation.

When adding chemicals, there must be coagulation tank like this tank.

- **Solid Contact Clarification**

Coagulation is improved by increasing floccus concentration by return the sludge. This can be made by collecting coagulation and clarification in one place called (Accelerator) or (Pulsator), and this is achieved by a highly concentrated sludge blanket consist from suspended particles. Vertical speed is increased in this place to 6 meter/ hour according to the type of clarification tank, and in this way high quality water can be attained despite of the turbidity of raw water.

These tanks are supplied with surplus sludge sump that is removed automatically. Sedimentation by using sludge blanket method improves clarification and this leads to higher efficiency with the same quantity of added chemicals.

- **Using sedimentation plates in sludge contact clarification**

By adding repeated plates in accelerator or pulsator with sludge blanket, this improves and increases the efficiency of clarified water with the same speed from bottom to the top, by retaining surplus floccus that escapes from sludge blanket.

Super Plusator

It consists of clarification tank wit pulsator system and inclined panels provided with deflectors. These panels are inclined in the suspended sludge blanket where sludge is settled in the low panel that is exposed to water current heading to the bottom and this pushed it to the bottom of blanket sludge. Water generated from the movement of sludge to the bottom is collected over the higher panel as it comes out from the top of the tank and this leads to improve sludge concentration and increase its speed twice the speed in pulsators tanks with sludge blanket.

Components: (static sedimentation)

Circular or rectangular Reinforced concrete tank includes the following:

- weirs with baffles
- Harrow for sweeping the sludge.
- Bridge for operating baffles.
- Incoming Water pipe.
- Water outlet pipe.
- Waste pipe of sludge settled at the bottom.

The following must be taken into consideration:

Install check valves in incoming water pipes and discharging pipes of sludge.

Design Rules:

Rectangular Tanks:

- Tanks shall not be less than two.
- Tank length= 3-5 width.
- Width= 2-4 depth
- Water depth= 2-4 meter.
- Retention period= 2-3 hours.
- Loading rate on weirs:

Starts from 150 m^3 /m/d and shall not exceed 200 m^3 /m/d, and in case of (v notch). shall not exceed 300 m^3 /m/d.

- Horizontal speed shall not exceed 30 cm/ minute.
- Length of the tank shall not exceed 50 meter.
- Bottom mile shall be %1-2. Mile direction in the place of collecting deposits shall be towards entrance of water flow.
- Water speed in outgoing pipes ranges between 0,5 -0,7 m/s.
- Water speed in outside pipes ranges between (20-45 m^3/m^2/day).
- The diameter of deposits disposal pipe shall not be less than 150 mm, settles disposal must be regular.

1-6 Clariflocculators:

Clarification and coagulation are made in one circular tank combining an internal space for coagulation and external space for clarification as shown in figure no. (2-7).

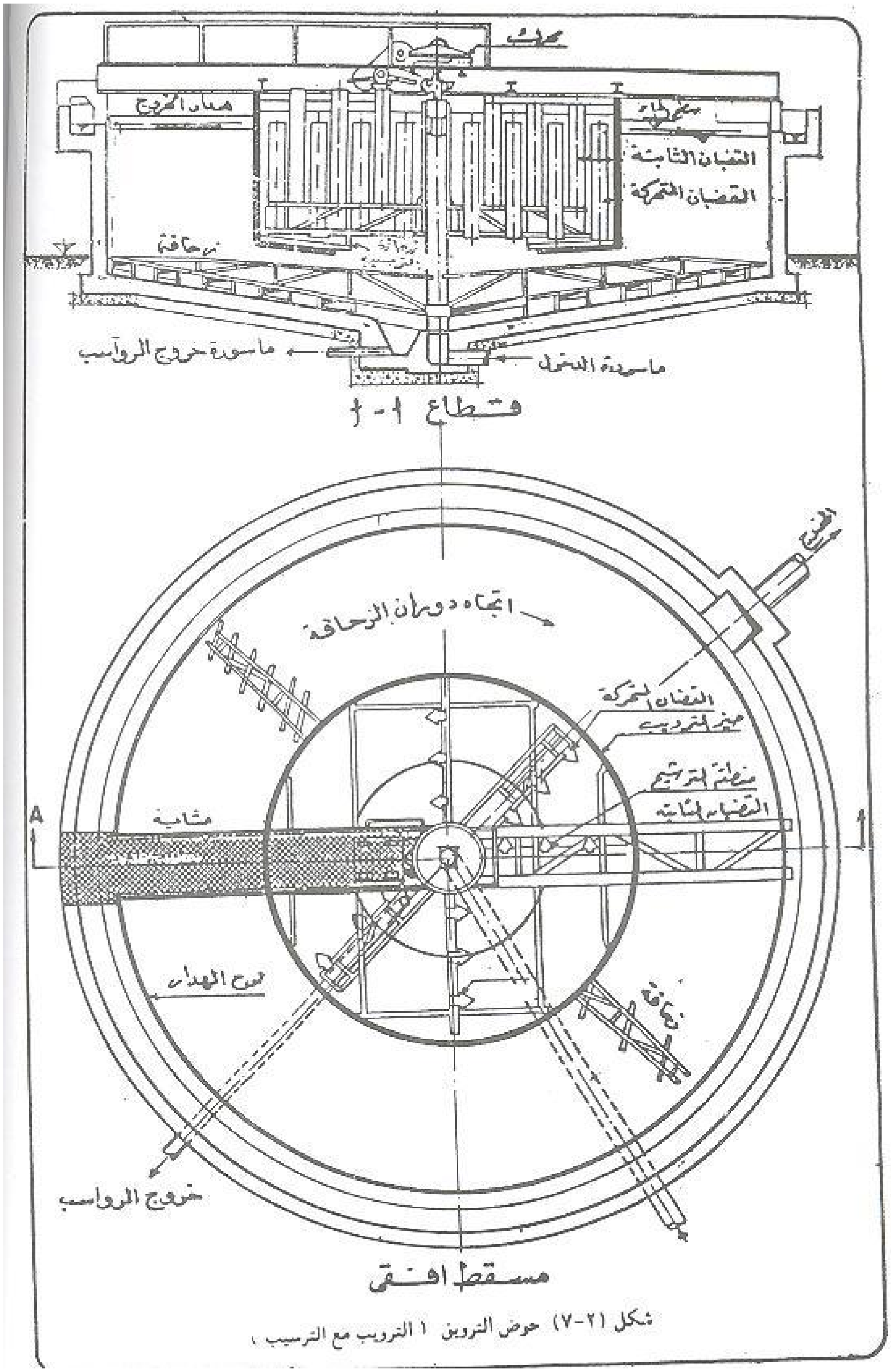


Figure no. (2-7). Clariflocculators Tanks

Component:

Circular reinforced concrete tank includes the following:

- Harrow for sweeping the sludge.
- Bridge
- Mechanical flippers
- Weirs
- Incoming Water pipe.
- Exit Water pipe.
- Exit pipe of sludge.

The following must be taken into consideration:

Install check valve on incoming water pipe and sludge disposal pipe.

Design rules:

Concerning coagulation area:

- Retention period from 20-40 minutes.
- Water depth from 2-3 meter.
- Peripheral speed for mechanical flipping shall be within 3 m/s.
- Coagulation Capacity ranges between %15-25 of total capacity.

Sedimentation place:

- Diameter of tank shall not exceed 40,0 meter.
- Retention period ranges between 2-3 hours.

- Over flow rate is 20-45 $m^3/m^2/day$.
- Flow rate on weir ranges from 200-300 $m^3/m^2/day$.
- Diameter speed shall not exceed 30 Cm/M
- Bottom inclination ranges between % 2-4. Inclination in the place of deposits collection shall be towards entrance of water flow.
- Diameter of deposits disposal pipe shall not be less than 150 mm and deposits flow must be regular.
- Water speed in outside pipes ranges between 0, 5-0, 7 m/s.

1-7 Filters:

Purpose:

Cohesion of suspended particles in treated water on sand grains existed in the filter- because of coagulants if it is used- therefore settled where a gel surface of fine suspended particles and other possible fine creatures is formed on sand.

Filters are divided into two types:

A- Slow Sand Filter

Component:

Concrete tank contains layer of sand grains with 60-120 cm and actual diameter of 0,25-0,35 mm, and coefficient of 1,7- 2,0. Under this layer, there is a gravel layer of 30-60 cm thick and water level above sand amounts 150 cm.

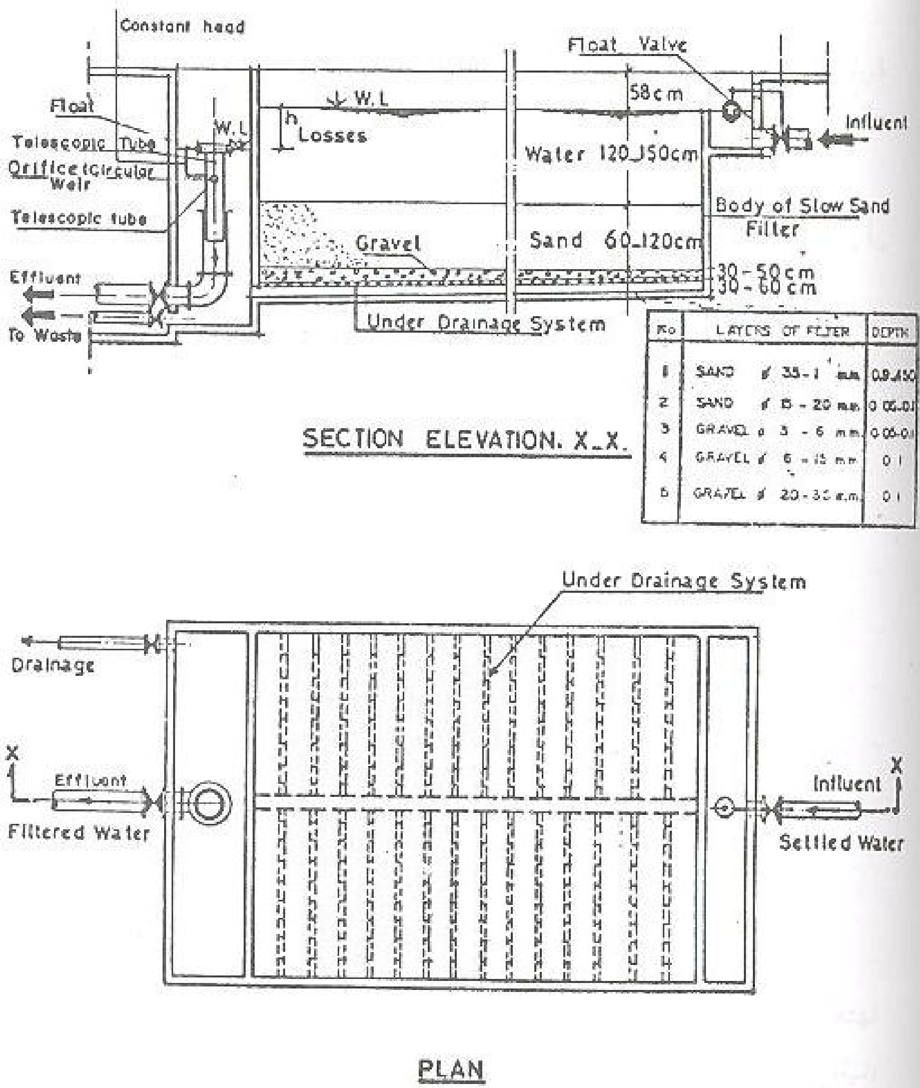


Figure no. (8-2)

Slow Sand Filter

Under gravel, there is under drainage system for filtered water, and it is either putty blocks with spaces, or cement or plastic punctured pipes at 30-60 meter height.

Slow sand filter is washed manually by scrapping the upper sand surface manually until the sand thickness amounts 30 cm. See figure no. (2-8).

Design Rules:

- Filtration rate ranges between 3-5 $m^3/m^2/day$
- Thickness of gravel layer is from 30-60 cm.
- Speed of water flow into filters is 0,5-0,7 m/s.
- Water speed into drainage canals of filtered water shall not exceed 0,6 m/s.
- Thickness of sand layer is between 60-120 cm.

B- Rapid Sand Filter

Components:

- Concrete tank consists of sand layer with 5-7 cm thick, under which there is a layer of graded gravel of 30-60 cm thick. Water level above filter surface is 150 cm. Under such gravel layer, there is a network of punctured piping that is distributed regularly throughout the areas of the filter, or punctured concrete slabs with plastic nozzles that are distributed regularly (water must be treated first with coagulants before being transferred to filters).

- Filter is washed by allowing air and filtered water to pass in a reverse direction to filtration after dismounting sand grains by compressed air. Washing is made when pressure head loss reaches to 1,5-3 m. figure no. (2-9).

Design Rules:

- Thickness of sand layer ranges between 50-70 cm, and the diameter of sand grains is 0,6-1, 5 mm, and coefficient of 1,35-1,50.
- Thickness of graded gravel ranges between 30-60 cm.
- Filter area ranges between 40-60 m^2.
- Minimum filters number= $0,044\sqrt{\text{station flow } (m^3/day)}$
- Filtration rate ranges from 120-180 $m^3/m^2/day$.
- Wide: long ratio = 1: 1, 25 or 1:2.

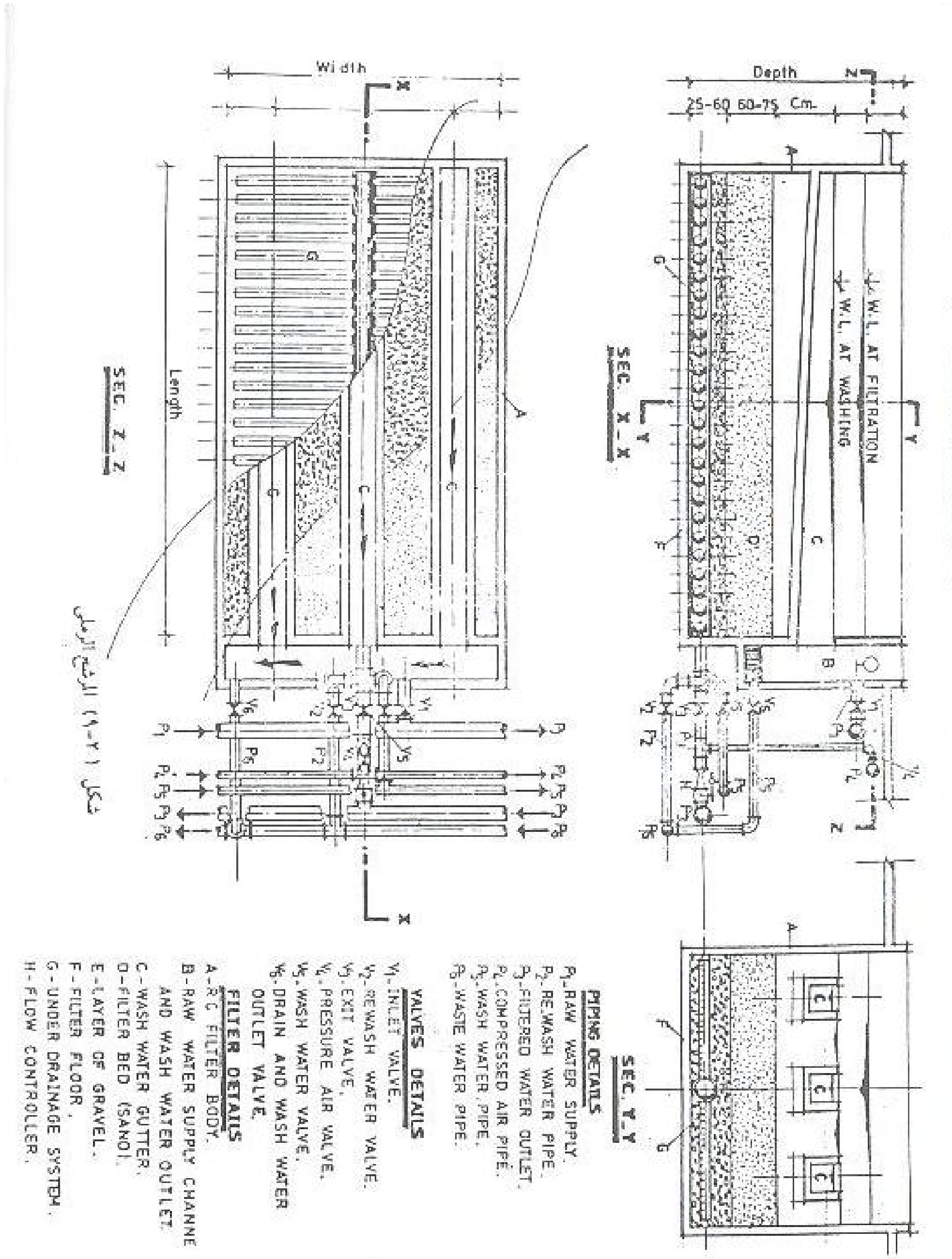


Figure no. (2-9) Sand Filter

1-8 Activated Carbon

It is sometimes added to raw water to be treated- especially in the occurrence taste and odor due to high density of algae and floated materials in the surface of water source. This is a highly active method to remove odor and taste.

Usages

It is used to ensure high quality of water especially in cases of industrial water, or when assurance of throwing industrial wastes or petroleum materials in water source has led to a significant change in taste and odor.

Addition method

Activated carbon is added to treat taste and odor as powder before coagulation process or in quick flipper of the coagulant or in the distributor, by dosages depends on the density and type of pollutants. This dosages ranges between 8-25 PPM (gm/m^3), and size of gravels is between 0,3-0,7 mm, and it is added by using equipments similar to the equipment of adding lime either by weight or size.

There is another method to add activated carbon by setting up carbon pressure filters. Filtration media are totally from activated carbon grains, or from sands + carbon layer with 10-25 thick, and size of grain is 0,8-2,2 mm, and its lifetime is 2-3 years. Design must take into consideration that it activated carbon is not lost during washing filters with water, air, or by both of them.

1-9 Chlorination

Purpose of Chlorination:

The purpose of chlorination is limited to oxidizing algae and harmful fine creature that cause diseases such as bacteria and normal microbes with shells, with fixed dosages in certain phases of treatment process in away not affecting the health of humans and animals, and without changing taste and odor of water.

Chlorine is considered the mist easy, cheap, and common substances used in this respect in all water treatment plants.

Design Rules:

Chorine dosage to be added to water is calculated in three phases as follows:-

A- Preliminary Chlorine

It determines the chlorine demand of raw water, according to the volumes of bacteria, algae and suspended particles exist in water. It is added in raw water pumps and one minute at least before coagulation.

B- Middle Chlorine

it is added to clarifies water after it get out of the coagulant if the chemical test proves that the remaining chlorine is lacking and that water coming into filters does not have more than 0,1 PPM.

C- Final Chlorine

It is added to water after filtration after conducting chlorine demand test for half an hour. The remaining chlorine is measured after contact that last for 20-30 minutes at least. The required dosage is determined as the remaining chlorine shall not be less than 0, 20 PPM, provided that an additional ratio is added to eliminate contamination that may be found in water network. Another ratio can be added in network to compensate for the lack in remaining chlorine.

1-9-1 equipments Machines for adding Chlorination

Chlorine adding unit consists of the following machines and equipments:-

1- Equipments for ejecting chlorine solution.
2- Equipments for ejecting chlorine gas.
3- Chlorine cylinder.
4- Ejector.
5- Ejection pumps.
6- Ejection equipments in pipes and tanks.

According to the following details:

1- Equipments and devices for chlorine injection

This system is used in compacted water stations with capacity that not exceed $100m^3$ / hour and consist of:

1-A- Tanks for preparing solution

1-B- Metering pumps.

1-C- Connecting pipes from solution tanks to ejection places.

A- Tanks for preparing solution:

It consists of tanks for preparing chlorine solution whether Calcium Hypochlorite or sodium Hypochlorite.

Solution is prepared by mixing powder by %30-60 in case of Calcium Hypochlorite, or by mixing chlorine solution with concentration of %0,1-1 in case of sodium Hypochlorite. It is mixed with water to obtain the required dilute solution to be ejected in the unit.

The tank capacity must be enough for operating the station for a period not less than 24 hours, and considering maintenance and sudden defects. These tanks are made of G.R.P, rubber, propylene, or other material that does not affect or oxidized by chlorine.

B- Ejection pumps:

There are two types of pumps, porcelain or polyethylene plungers, or diaphragm. Both of them have meters on discharge pumps that determine the quantity of solution discharged from the pump in a specific time (liter/hour).

C- Transferring pipes:

It consists of u.P.V.C, H.D.P.E, or its equivalent, complete with the valves and accessories of the same type of the pipe. Pipes must endure pressures not less than 6 bar, and that ejection method whether in pipes or tanks is made according to the specifications hereunder.

2. **Equipments and Machines for adding chlorine gas:**

There re two types; pressure type and vacuum type that is currently used for its total safety in its uses, as it pulls the air from the atmosphere if there is any crack or defect in the machine. Therefore, it does not cause any leakage inside machine compartments. Flow of the equipment is determined by gram or kilogram per hour. When determining the flow of the equipment, it must be sufficient to the maximum dosage volume required whether the final or preliminary chlorination + %25 additional. Pipes of surplus chlorine must be connected outside chlorine warehouse and in a level that does not affect the workers in the station.

3- Chlorine Cylinder:

It is a high quality iron containers with different capacities 50-200 -500 and 1000 kilogram. The cylinder endures air test pressures not less than 25 bar, and water test pressure not less than 45 bar , taking into consideration welding the connection the walls of cylinder of 50 kg capacity with its floor. Chlorine volume that can be taken from cylinder is determined according to the cylinder capacity and temperature. if one cylinder is not sufficient for the required chlorine volume , more than one cylinder can be connected in parallel or by using steamer as per the following table:

Cylinder capacity (Kg)	50	500	1000
Maximum drawing quantity (Kg/Hour)	1	8	10

If temperature became less than 10 degrees, it is recommended to operate handling cylinder to prevent the frozen of cylinders. It is prohibited to expose cylinders to direct flames or walls heat. Water bath can be used for handling cylinders when temperature is decreased.

All cylinders must be provided with safety fuses whether in valves or in the cylinder bottom. These fuses are opened automatically when the temperature exceeds the specific limit. Cylinder should be tested once each two years at least and it shall not be filled with gas before obtaining certificate providing that necessary tests and inspections are performed which are:

- Testing liquid pressure.
- Testing air pressure.
- Indentation test.
- Testing thickness of walls and bottom.
- Testing valves installed.

Steamers are used when the chlorine quantity to be drawn from cylinder amounts 75 kg/hour, in order to transfer chlorine from liquid to gas using steaming room inside water or oil bath that is heated by submerged electric heater. Gas goes out from the opening of steamer exit to addition equipments

Steamers are supplied with control equipments, indicators of water level, water temperature, gas temperature or pressure, and measuring equipment to ensure safety operation, as well as monitoring and alarming equipments if water level or temperature is decreased, thermostat to control temperature, cathodic protection equipment in addition to supply connection and water screens.

Available capacities of the steamers are 75, 120, 150 Kg/Hour.

4- <u>Ejector:</u>

It is an equipment that consists of conic throttle that allows gas drawing from the narrow space whenever water speed increases. This is shown in figure no (2-10). When water passes from A- C, the discharge takes place in point B where gas is drawn.

Each equipment of different capacity has different design of (ejector) according to different companies manufacturing the equipment.

5- Ejection Pumps

It is used when ejecting chlorine in pipelines and pump pressure must be = line pressure+ 2, 5 bar at least in order to allow the ejection of the solution in the ejection point.

Pumps capacity differs according to the size of the machines installed on it as per the following table:

Capacity Chlorine Equipment	Minimum Pump Flow
1kg/ hour	0,3-0,5 m^3/ hour
2kg/ hour	0,6-0,8 m^3/ hour
4/5 kg/ hour	1,2-1,5 m^3/ hour
10 kg/ hour	3,0 m^3/ hour
20 kg/ hour	6,0 m^3/ hour
50 kg/ hour	15,0 m^3/ hour
75 kg/ hour	22,0 m^3/ hour
100 kg/ hour	30,0 m^3/ hour
120 kg/ hour	35,0 m^3/ hour

6- Ejection method in pipes or tanks

Figure no. (2-11) demonstrates this method.

Chlorine storehouse:

Introduction:

Chlorine storehouses are the places where chlorine cylinders are safely kept. Storage is made in a proper way that does not affect cylinder safety and facilities of the station and citizens.

<u>Selecting storage location:</u>

- There are many terms regarding selecting the location of chlorine cylinders storage. These conditions are as follows:-
- It must be close to the operation building of cylinders, containers, and equipment used for adding chlorine.

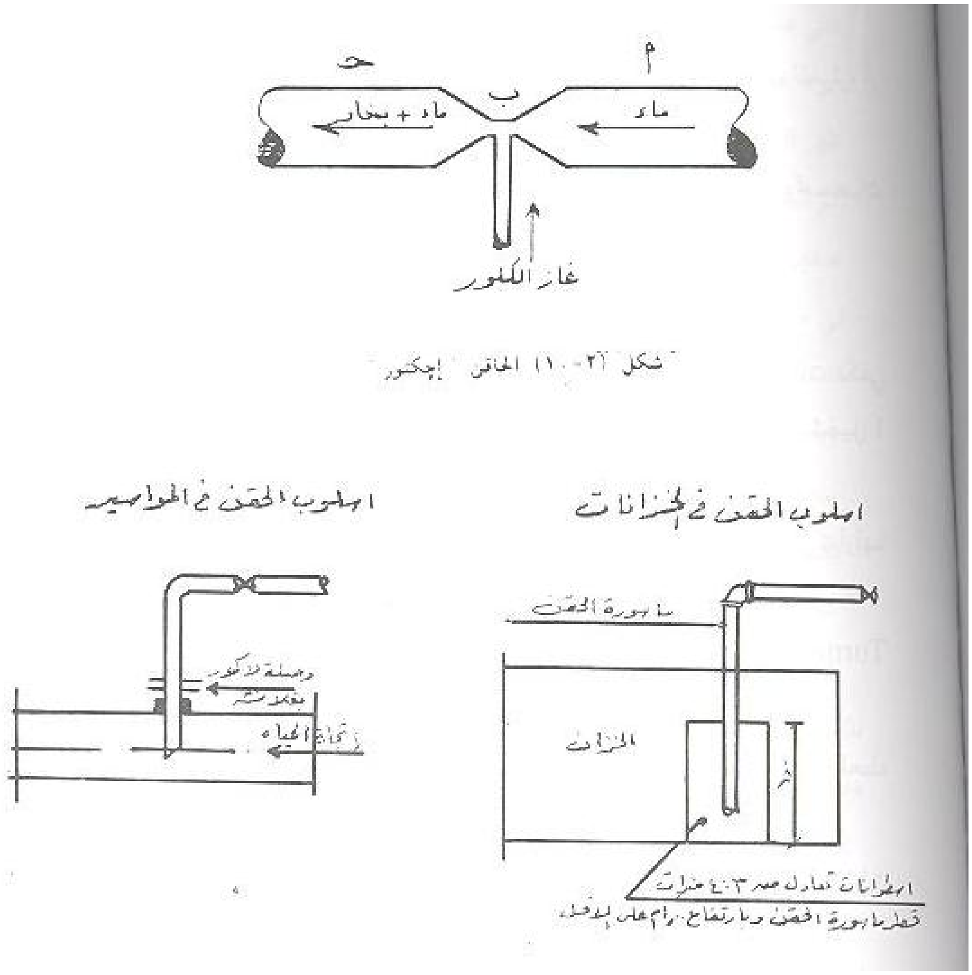


Figure no. (2-11) ejection method

- It must be close or overlooking Main Street inside the station for easy transport and handling.
- It must be away from fuel storehouses, workshops and any other source causing heat, or flammable pipes like Acetylene and oxygen.
- It must be away from residential compounds, administrative buildings, and workers gathering.

Storehouse specification:

- Size and capacity of the storehouse must be suitable to contain cylinders or containers that can operate the station for continuous ten days, in addition to two groups under operation (main and subsidiary).
- Containers must be stored vertically for easy circulation and transfer.
- Containers must be stored horizontally with turnnions for each container to prevent it from rolling and for easy rolling around its axe.
- Containers must be stored in two or four parallel rows according to the station size and number of containers circulated.
- Distance between axes of containers must be 120 cm and the space in front and behind containers must not be less than 1, 5 meter.
- Store must have concrete flooring, strong concrete structure, and ventilated concrete ceiling that isolate sun rays directed on cylinders and containers, provided that temperature must not exceed 45 C.
- Height of storehouse ceiling from the floor must not be less than 5,5 meter.

- Store house of chlorine cylinders must be supplied with electric winch that its load is not less than 2,5 tone. This winch is hanged on a metal beam of I shape, with 30 cm and its height from storehouse floor is not less than 5,0 meter, and 2 meter projection outside the storehouse entrance. This winch allows the circulation and handling of containers from and to vehicles.
- Winch is used for each roe of containers or a winch with a circular beam above each two rows.
- In case of non- exposed small storehouses, it must be supplied with mechanical ventilation equipments (exhausts) with sufficient capacity to change the storehouse air once each four minutes at most.

The discharge of this exhausts is directed to a room by connection boxes (openings) near the level of the storehouse floor.

All chlorine storehouses must be provided with alarms in case of chlorine leakage and methods for fire fighting (hoses).

Protection method against the leakage of chlorine gas

Introduction:

Storehouse of chlorine cylinders must be provided with protection system against leakage gas with treatment of leakage to ensure safety and security of workers in the site.

The system consists of the following components:-

1- Measuring system of chlorine concentration in the storehouse by alarming when chlorine concentration amounts 0,3 PPM in the storehouse air, and operating comprehensive protection system when concentration exceeds 0,5 PPM. This is made by using sensors placed in the storehouse as well as in the room of chlorine equipments affiliated to the storehouse.

2- Protection method (equilibrium tower) which includes:

2-1 pumping sodium hydroxide which concentration is not less than %10 by using special pumps that endure sodium hydroxide concentration up to %25. Solution comes out from the top of equilibrium tower through tower designated for this (figure no. (2-11), by u.P.V.C pipe or its equivalent, with side holes as shower.

2-2 air exhausts installed inside the storehouse that exhaust contaminated air and direct it to balance tower to contact with the shower of sodium hydroxide and interact with it.

3- Ventilation fans

Installing two groups of exhausts at (0,5-0,7 meter) from ground surface, and another group of Centrifugal fans at (1,0 meter) from ground level to deal with minor leakage of gas inside storehouse or inside equipments storehouse.

Note: all chlorine facilities inside storehouse or equipment storehouse must be painted by anti- acids painting, and that upper windows frames are made of wood or aluminum and can be opened easily from beneath in emergencies.

4- Special protective equipments (masks) supplied with carbon filters, as well as masks that cover workers face. These masks are supplied with compressed air cylinders to deal with chlorine equipments or the cylinders existed in the storehouse in case of emergencies.

Disinfection by Ozone

Oxidization of organic substances and chemical composition of water, as well as disinfecting water from bacteria and viruses by using Ozone (O_3) instead of chlorine.

Ozone is more powerful gas than chlorine and has great ability in oxidization and disinfection processes and disposal of bacteria, algae, Ferrum, and manganese within small ratios (up to 0,7 PPM). This is not applied in Egyptian water treatment station until now, as it needs huge amount if electricity (high pressure). It also has efficiency in removing viruses that are not affected by chlorine.

It has many advantages including that it is extracted from atmosphere after being dries from moisture. It can also be derived directly form oxygen. One of the main reasons for not being used in water stations is that it does not give fixed remains as it is directly transformed to dissolved oxygen in water. Therefore, chlorine must be added after ozone to make sure that there is remains in water to prevent any potential contamination in networks and in emergencies occurred in tanks.

1-10 Sludge Treatment

Sludge resulted from water treatment process is separated or filtered from clarification tanks, as well as the sludge resulted from filters washing proves. The source of suspended particles in the sludge is raw water before being treated in addition to substances as metal hydroxides (metal- manganese), and other substances added during treatment (coagulation) or activated chlorine powder if it is used.

When using filters only, the sludge resulted from washing filters are formed of suspended particles with concentration of 200 to 1000 PPM, which is higher than the permissible limits to be returned to water.

When using clarifiers with filters, sludge must be separated from coagulants and return it or part of it to the entry of treatment process to enter again with raw water in order to improve coagulation process, whereas filter-washing water is collected and dried in drying tanks or using mechanical methods in drying.

2- Mechanical Design

2-Mechanical Design

2-1 Intake

2-1-1 Coarse Screen

- It is used in water intake to retain substances and big floated objects in water passage, and prevent it from entering to main connecting pipes of raw water sump or pump to treatment process.
- It consists of group of mild steel bars with circular sectors of 1 to 1,5 inch (25 to 40 mm), or rectangular sectors of 1/2 × 2 inch (15× 50 mm) and distances are (100) in the intake of the pipe and reaches to (25mm) in shore intake.
- It is installed at the beginning of the concrete or iron structure that bears the intake pipes, or inside a metal frame inclined to the concrete beams of shore intake.
- It is cleaned manually and daily by using clutch to avoid the accumulation of floated objects like water hyacinths and alike and prevent it from blocking water entrances to station.

2-1-2 Mechanical weed Screen

- It is used to retain and remove weeds and fine solids that are passed through the fixed coarse screen, then collect it and remove it away from the path of production line and water treatment.

- It consist of panels or baskets of galvanized steel mesh or stainless steel, or polyester inside stainless steel frames fixed on a joint steel belt.
- It has vertical or rotary band.
- Clear opening of mesh ranges between 3×3 mm to 10×10 mm, and the diameter of mesh wires is between 2 to 2, 5 mm.
- Spaces between the basket frames or between panels shall not exceed 3 mm.
- Efficiency of coarse screen in water flow is %50.
- Mesh area (submerged screen)= $\dfrac{\text{Flow rate (} m^3/s\text{)}}{\text{Water speed (m/s)} \times \text{Efficiency}}$

With calculating water speed to be about 0,6 m/s.

2-1-3 Isolating Blocks

1. It is used with shore intake in cases of emergencies or when there is a need to isolate water and prevent it from entering to the station during maintenance or when requiring the control of quantities of raw water required, through specific layer away from the bottom and away from surface.
2. It consists of teak wood, or fabricated steel.
3. It is slipped inside steel conduits fixed longitudinally beside the openings of concrete intake.

2-1-4 Isolating Gates

- It is used with isolating blocks in case of quick lock to prevent water from entering to the station in shore intake. It is also used when isolating the storehouses of mechanical weed screen.
- The main gate is made of cast iron or ductile iron or fabricated steel, supported with fins to strengthen it and protect it against indentation or broken in case of over-pressure.
- Slept inside steel conduit fixed vertically.

2-2 Sump

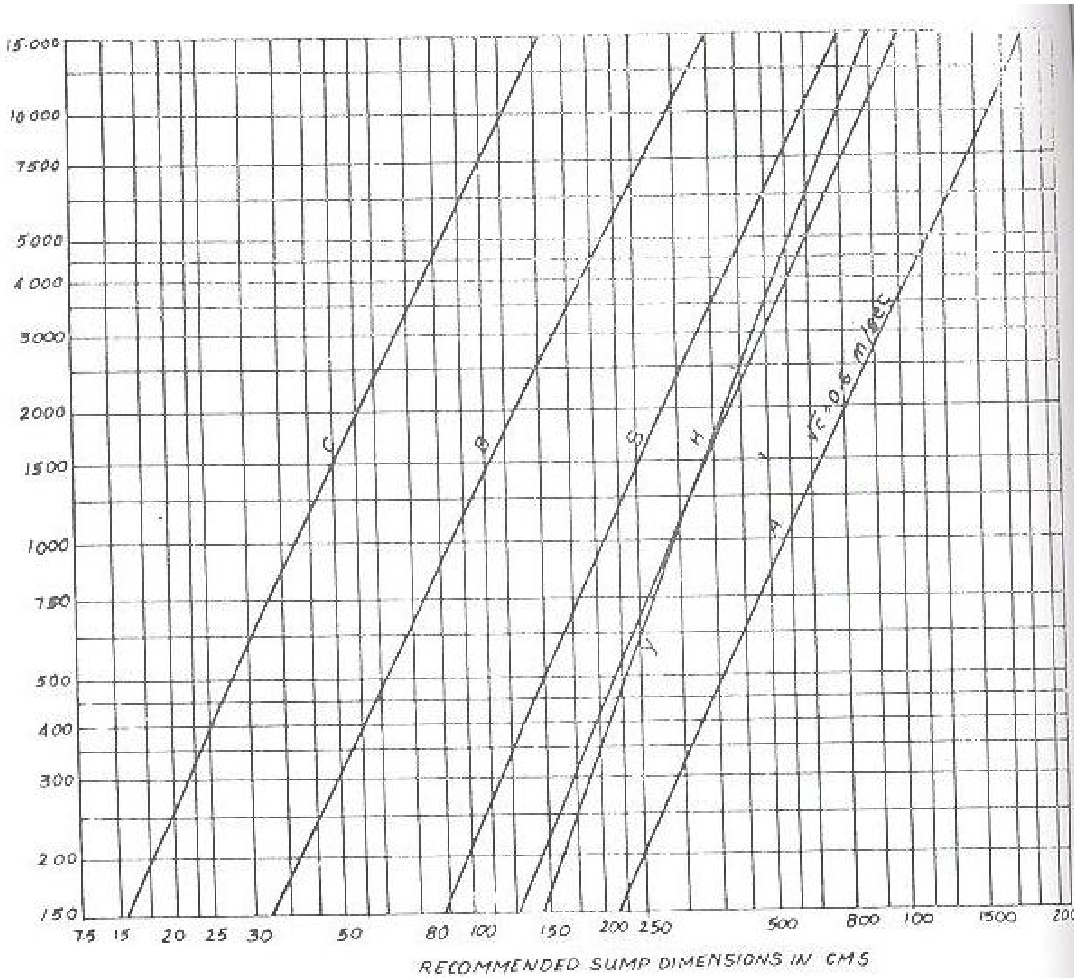
The determination of dimensions of suction pipes in the sump depends on the maximum flow rate of the pump (Q).

The determination of sump dimensions also depends on the speed of water inside the supplying pip line of the sump (Vp), and retention period is 5-10 minutes.

Figure (2-12) shows the relation between pump flow and standard dimension of the sump.

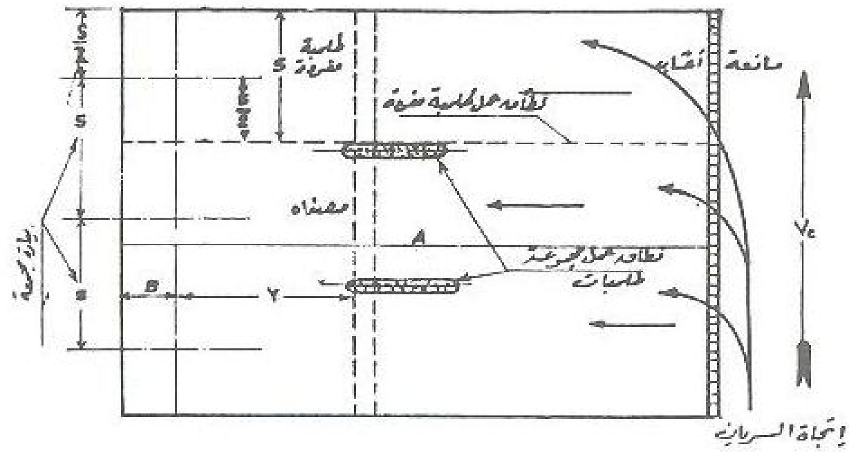
Figure (2-13) it is a drawing of the sump showing the standard dimensions attained from the previous figure.

Figures no. (2-14, 2-15, 2-16, 2-17) shows some of planning of recommended sumps with the specifications stated next to it.



شكل رقم (٢-١٢) : العلاقة بين تصرف الطلمبة باللتر / ثانية والأبعاد القياسية للبيارة بالسنتيمتر

Figure no. (2-12: Relation between pump (liter/ seconds) and Recommended Sump Dimensions in CMS



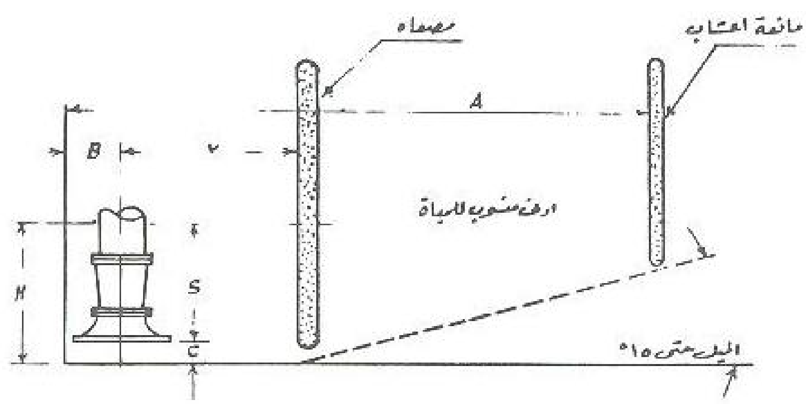
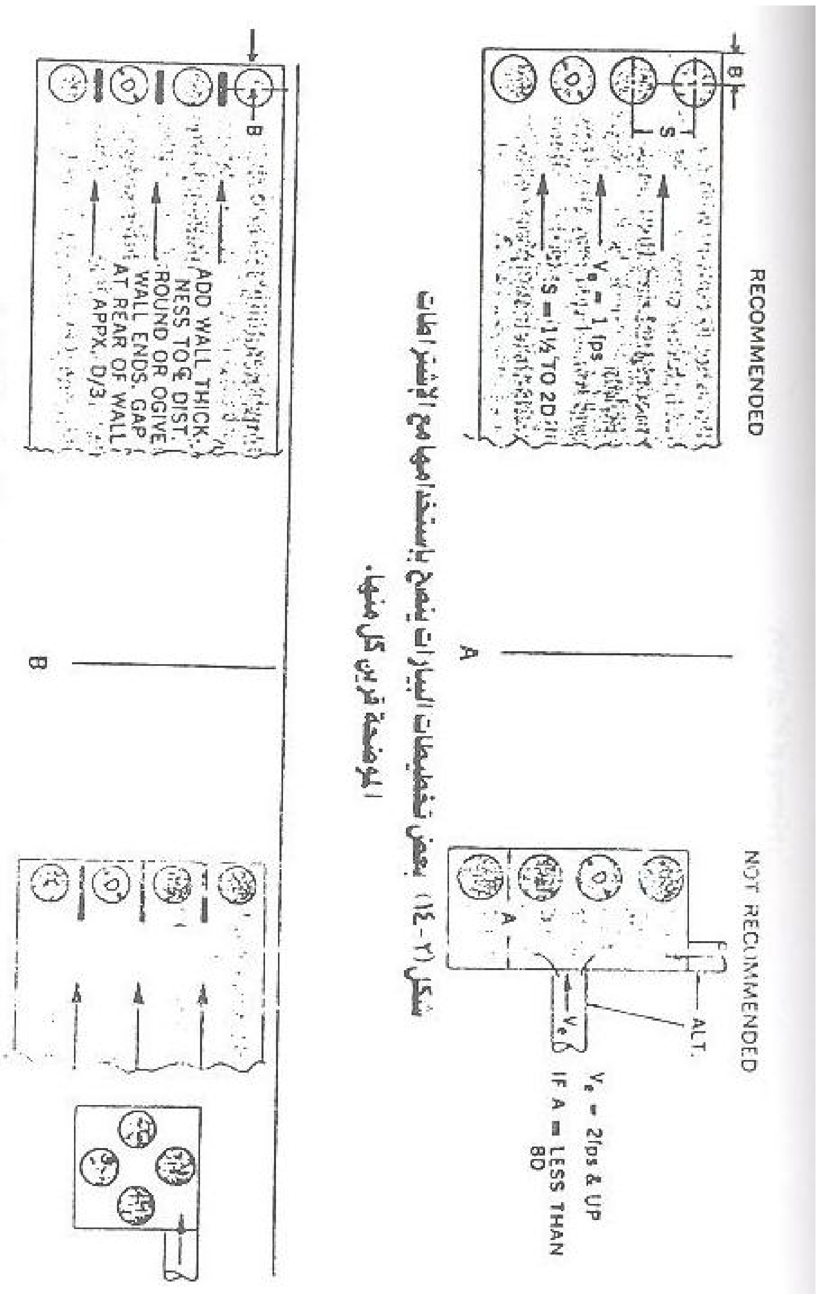


Figure no. (2-13) It is a drawing of the sump showing the standard dimensions used in figure no. (2-13)



شكل (٢-١٤) بعض تخطيطات البيارات ينصح باستخدامها مع الإشتراطات الموضحة قرين كل منها.

شكل (٢-١٥) بعض تخطيطات البيارات ينصح باستخدامها مع الإشتراطات الموضحة قرين كل منها.

Figure no. (2-14) some planning of recommended sumps with the specifications stated next to it.

Figure no. (2-15) some planning of recommended sumps with the specifications stated next to it.

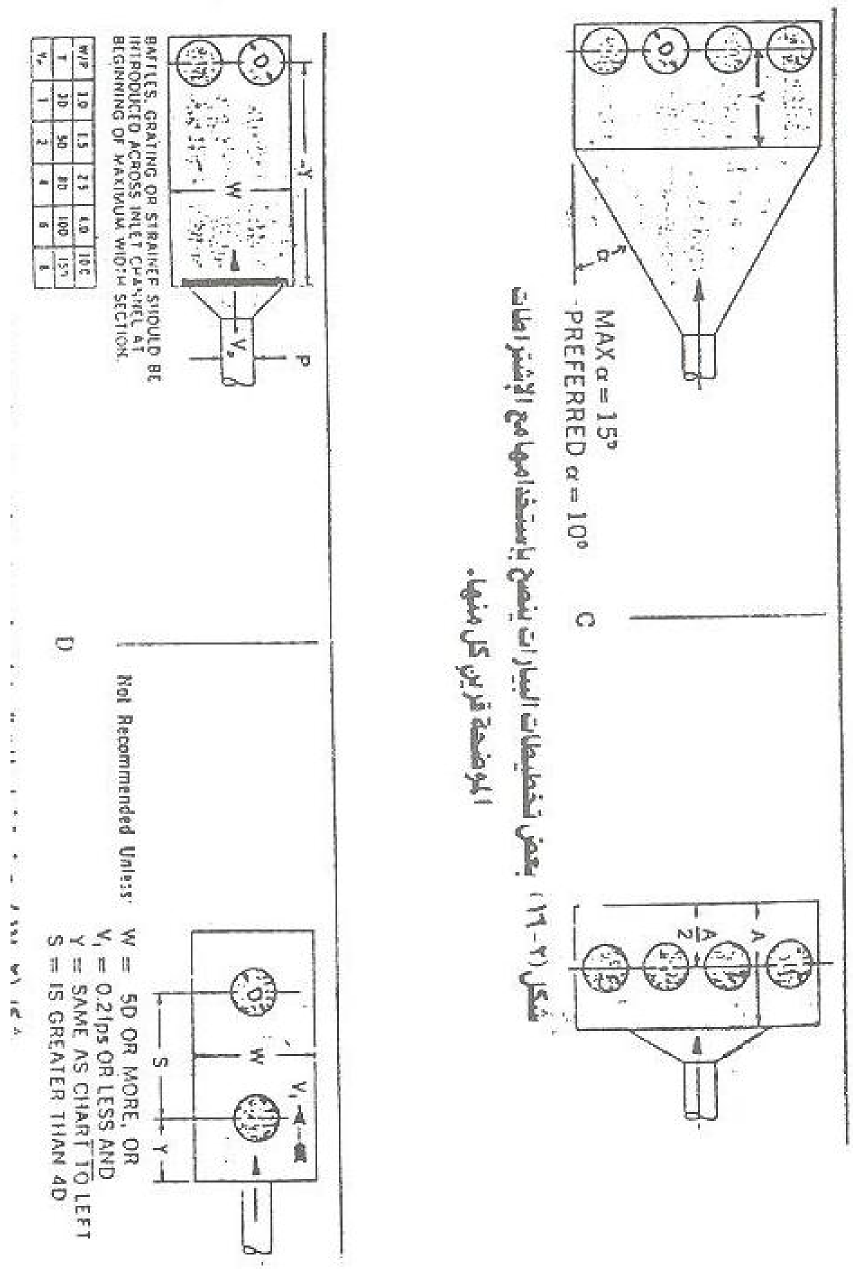


Figure no. (2-16) some planning of recommended sumps with the specifications stated next to it.

Figure no. (2-17) some planning of recommended sumps with the specifications stated next to it.

Dimensions showed in these figures are the standard dimensions that prevent eddy, pump noise and vibration. If pump manufacturers proposed different dimensions and the selection of pup is right, it is necessary to reduce the speed of the pump or to increase the sump depth, whichever is less in cost.

If it is not possible to place an elbow in the beginning of suction pipe, and pipe entrance becomes horizontal, it is necessary to specify the least depth of water in the sump (distance between water surface in the sump and the inside tracer of suction pipe) S (figure no. 2-18)

$$S > 0.725\ Vp \times (di)^{1/2}$$

Whereas

Di = inside diameter of suction pipe (by meter)

Vp= speed in suction pipe (m/s).

Bill mouth must be used at the beginning of suction line to reduce entrance loss.

2-2-1 Speed in suction pip (Vp)

Bell mouth is to be used at the beginning of suction line to reduce entrance loss. In general, good design that provides safe operation is related to the head required from the pump; therefore speed in suction pipe as follows:

Required head from the pump	Speed in suction pipe
4,5 meter	7,6 m/s
Up to 15,0 meter	1,20 m/s
More than 15,0 meter	1,67 m/s

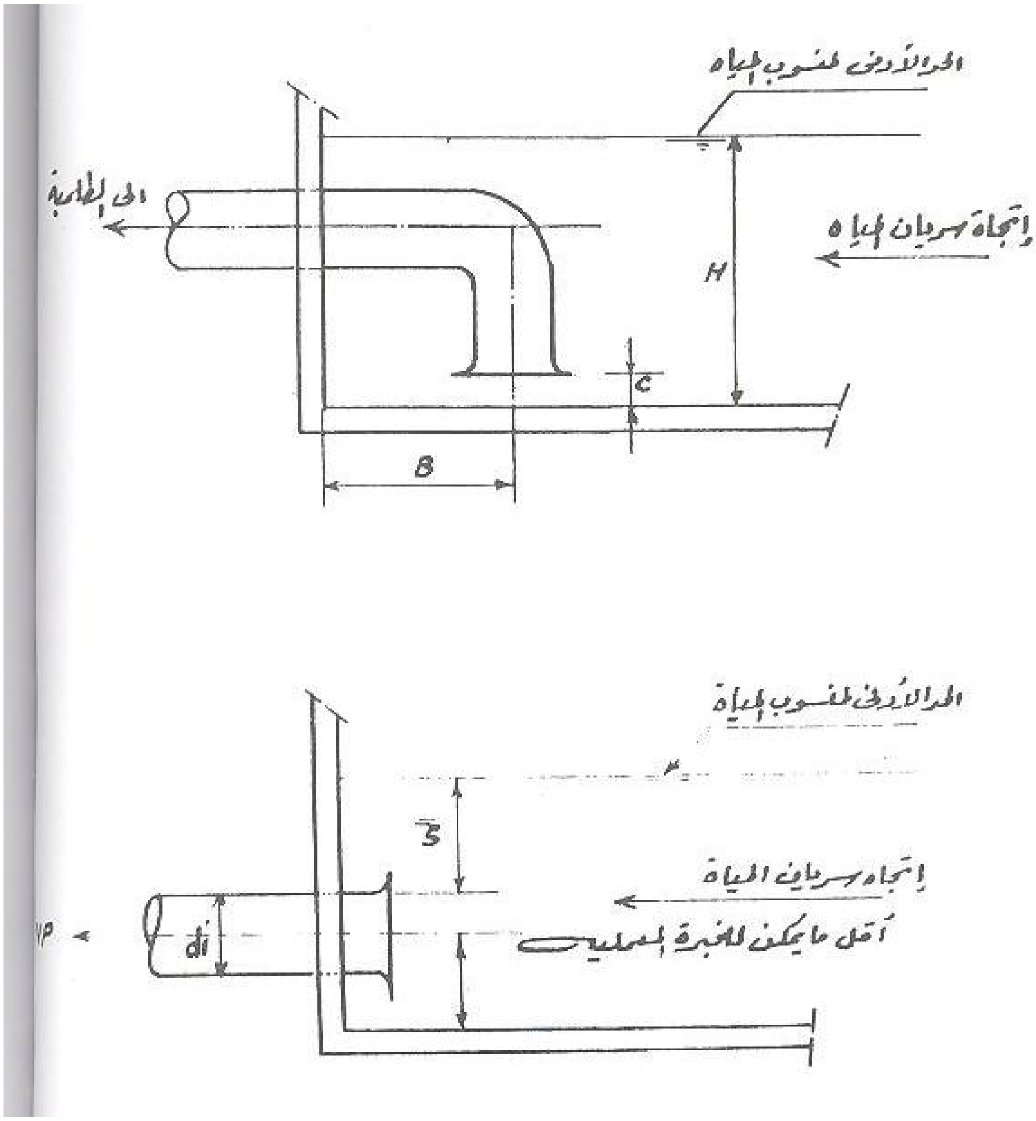


Figure no. (2-18) minimum water depth in sump

2-2-2 Approach Velocity

Velocity 30 cm/s is the optimum speed on water in suction sump to approach suction pipes of pumps. It must not exceed 50 cm/s knowing the maximum flow required for all pumps to be operated at rush hour, and considering the optimum approach velocity, the vertical sector of water in the sump is calculated, which gives better circumstances of entering and approaching at all water levels. Hence, the dimensions of the required sump can be selected.

2-3 Water Pumps:

Different types of centrifugal pumps are used in water booster works at water treatment station.

2-3-1 Selection of Pumps:

There are general factors that are used to select suitable pumps for all sites inside treatment plants. These factors are as follows:

- **Type of water circulated**: Raw water- filtered water- sludge- ground water
- **Type of pump**: vertical- horizontal
- **Installation**: dry pit, and it is either vertical or horizontal

  : Dry wet and it is either vertical, suspended, pr submersible
- **Flow**: volume of water removed by the pump across the sector of the discharge pipe of the pump in time unit. It is measured by cubic meter/ hour or liter/ seconds.
- **Head**: the power of the position used and transferred from the pump to the water to be pumped**.** It is measured by (atm), or (KP_a), or by measuring meter of water column.

2-3-2 Total Dynamic Head T.D.H

It is the difference between the pressure of dynamic flow of the pump and the dynamic negative pressure of suction (water meter).

$$T.D.H. = H_{d.dyn} - H_{s\ dyn}$$

Whereas

$\mathbf{H_{d.dyn} = H_{st.d} + h_{f.d} + h_{md} + h_{v.d}}$ **(1)**

$\mathbf{H_{st.d}}$ **=** static head measured between the axis of pump center and the surface of the upper reservoir.

$h_{f.d}$= Friction loss in discharge pipes $= f \dfrac{L}{D} \dfrac{V_d^2}{2g}$

$\mathbf{h_{md}}$**=** secondary losses in the accessories of discharge pipes (like valves and …etc)

$= \sum K \dfrac{V_d^2}{2g}$

$\mathbf{h_{v.d}}$ = speed loss in discharge pipe = $\dfrac{V_d^2}{2g}$

In addition to:

$\mathbf{H_{d.dyn}}$ **=** $H_{st.s} + h_{f.s} + h_{ms} + h_{v.s}$ (1)

$\mathbf{H_{st.s}}$**=** static head measured between the axis of pump center and water level in the sump.

$h_{f.s}$**= friction loss in suction pipes** $= f \dfrac{L}{D} \dfrac{V_s^2}{2g}$

h_{ms}**=** secon~~dary~~ losses in the accessories of discharge pipes $\sum K \dfrac{V_s^2}{2g}$

$h_{v.s}$= speed loss in suction pipe = $\dfrac{V^2{}_S}{2g}$

2-3-3 Net Positive Suction Head (N.P.S.H) Figure no. (2-19)

It refers to the minimum suction cases required to prevent Cavitation in the pump. It is the energy necessary to push the liquid to the pump fan to prevent cavitation and flashing. It is consisted to NPSH req and NPSH ava.

NPSH required is determined by testing and it is usually specified by the factory. Whereas NPSH Available, it is determined in the site at the station and it must be equal to (NPSH required) at least to avoid cavitation. Its increase ensure safety against cavitation and it is calculated as follows:

$N.P.S.H.av = (H_{abs} – H_{vap}) + H_{st.s} – H_f - h_{dyn}$

Whereas:

H_{abs}= air pressure generated at water level in the sump.

H_{vap}= steam pressure sucked at the center of the pump (at operation temperature) = 0,3 kg/cm^2 at 20 C.

$H_{st.s}$= static head measured between the axis of pump center and water level in the sump.

H_f= total friction loss and secondary loss in suction pump and its accessories.

h_{dyn}= decrease of dynamic pressure in the pump fan.

(Note): (all pressure units in the equation is made per water meter)

In case NPSHav is increased over the NPSHreq, bigger pump with less speed shall be used and vise versa.

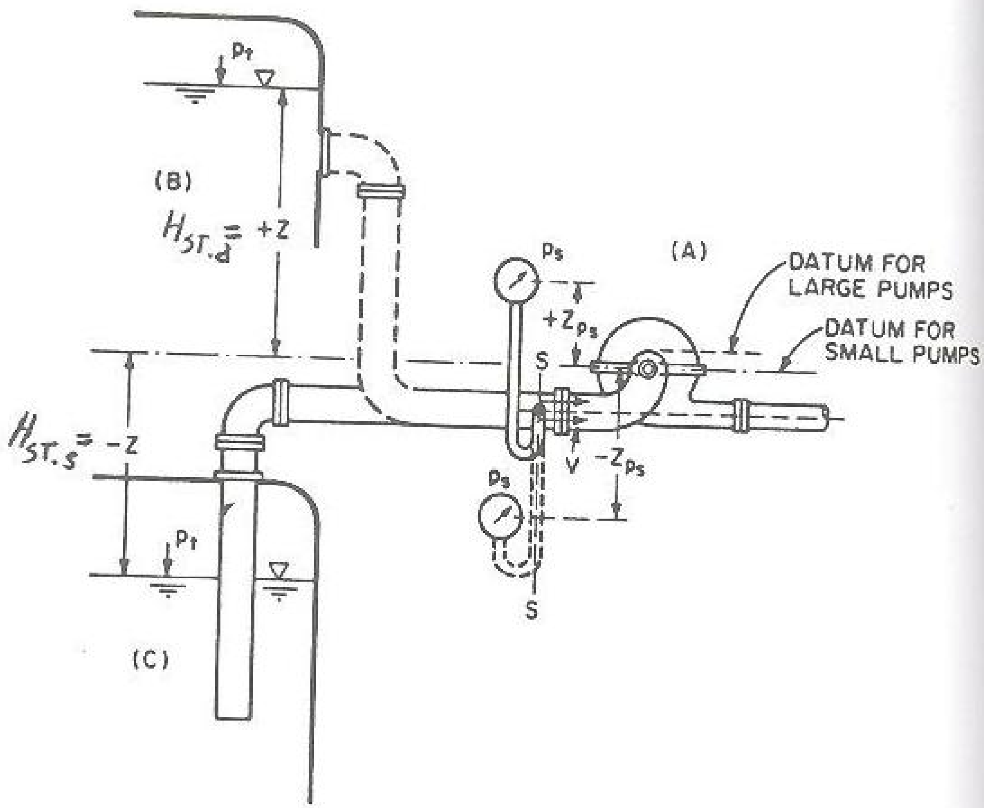


Figure no. (2-19) Demonstrative figure for Net Positive Suction Head

2-3-4 Decrease in Dynamic Pressure (Δh_{dyn})

Decrease in dynamic pressure results from the increase of speed in the back of the van that appropriate to the Ns at the fan entrance that is connected to HM.

HM б= Δh_{dyn}

Whereas б = THOMA coefficient for cavitation

Specific speed	20	30	40	60	120	150	180	240	300
Thoma Coefficient	0,052	0,096	0,16	0,21	0,53	0,67	0,82	1,26	1,8

Note: (1) suction pipe must be short and straight (as possible), with a bell mouth fixed at its entrance to reduce entrance losses. It is also necessary to use big diameter to reduce speed loss. Flow gauge must not be placed on the suction pipe

Head: Low head 3-12 Water Meter

Average head 15-45 Water Meter

High head 45-150 Water Meter and more.

Centrifugal pumps with single or double suction entrance are used with high and average head, whereas mixed and axial pumps are used for low head.

- Speed: Low speed 500-750 Turn/Minute

Average speed 1000-1500 Turn/Minute

High speed 3000 Turn/Minute

- Specific speed: it is the speed when the pump flow reaches $1m^3/s$ with 1 water meter head at its maximum efficiency:-

$$N_s = \frac{N.\sqrt{.Q}}{H^{3/4}}$$

Whereas:

N= turn speed of the pump (turn/minute)

Q= pump flow (m^3/s)

H= total head of the phase (water meter)

2-3-5 Impeller:

Impeller type is determined as per the specific speed and the following number:

10-35	Radial impeller is used
35-80	Francis impeller is used
80-160	Mixed flow impeller
More than 160	Axial impeller is used

This is for End suction impeller. Half flow value can be calculated in specific speed equation when using double suction impellers. Total head of the pup can also be divided into phases.

Figure no. (2-20) shows the change in impeller as per the approximate limits of the change in specific speed.

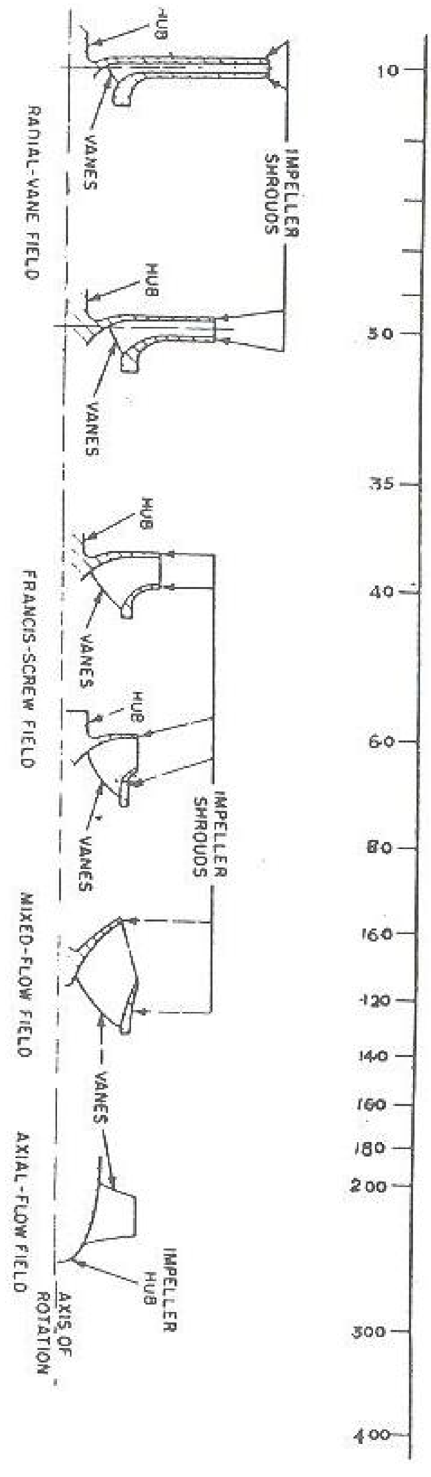


Figure (2-20) change of impeller shape as per the approximately dimensions by the change of quantitative speed.

2-3-6 Type of pump parts metal

Metal type of pump impeller and their components are determined according to quality and nature of the used water. In case of raw water free of sands and treated water with neural hydrogen ionization, impellers, shaft protection bushes and wear rings are made from Phosphorous Bronze. In case of high alkalinity or high acidity ground water, impellers and their components are made from stainless steel. In case of water containing sands and high percentage of sludge causing wear, the impellers are made from cast or ductile iron, while wear rings are made from stainless steel.

2-3-7 Pump Characteristic Curve

At constant speed of centrifugal pumps, pump flow Q increases as the head decreases and vice versa. So, these pumps are characterized by self-regulating. Internal power P, efficiency η and $NPSH_{req}$ depend on the capacity.

The relation between all of theses variables is represented by so called Pump Characteristic Curve, which shows its operation features.

Operation conditions of the pump are determined according to what is better to use flat curve or steep curve. In case of steep curve, pump capacity in lesser change than in case of flat curve at the same head difference conditions.

Pump manufacturers provide multiple characteristic curves for each pump, provided that pump body can accommodate impellers with different diameters affect the flow and total head of the approximate relation between each of them and impeller diameter as follows:

$$Q \propto D^2 , \quad H \propto D^2$$

There is also close relation between the flow, total head and power with the impeller speed as follows:

$$Q \propto N , \quad H \propto N^2 , \quad P \propto N^2$$

Fig (2-21) shows characteristic curves for centrifugal pumps for different diameters of the impellers.

Shape of the curve depends on:

A. Type of the pump (the impeller- screw enclosure of the pump)

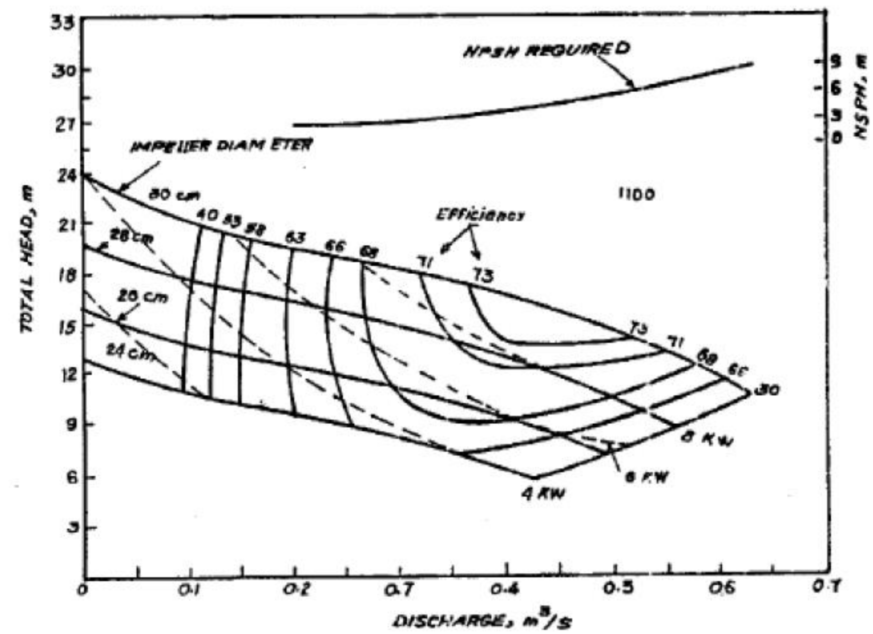


Fig (2-21): Characteristic curves of centrifugal pumps with different types of impellers

B. NPSH, manufacture accuracies, capacity and natural properties of the lifted liquid (viscosity).

C. Curvature of the curve according to specific speed for different types of impellers as follows:

- By increasing of the specific speed, inclination of the curve QH will become steeper, while efficiency curve becomes more acute and the power will have maximum value at the shut-off point.

- By decreasing of the specific speed, inclination of the efficiency curve becomes flat and power curve will have minimum value at shut-off point (Q = 0)

2-3-8 System Head Curve

The system consists of pipes, their accessories and different valves, and can add to them open channels and heirs. It can also include measuring devices and equipments work with liquid, tanks, etc.

- System head curve is drawn on Q-H curve as follows:

Starting point of system head curve is shown on the static levels (between water level in the sump and the highest level in the receiving tanks of the lifted liquid).

Friction losses in the pipes and all secondary losses in the system are calculated according to different flows from minimum pumps flow to maximum flow that the system can withstand. Different points are located to draw the head curve.

Fig (2-22) shows total head curve of a system consists of suction tank (1), receiving tank (2), pump and pipes line connecting between them and intersects with pump total head curve.

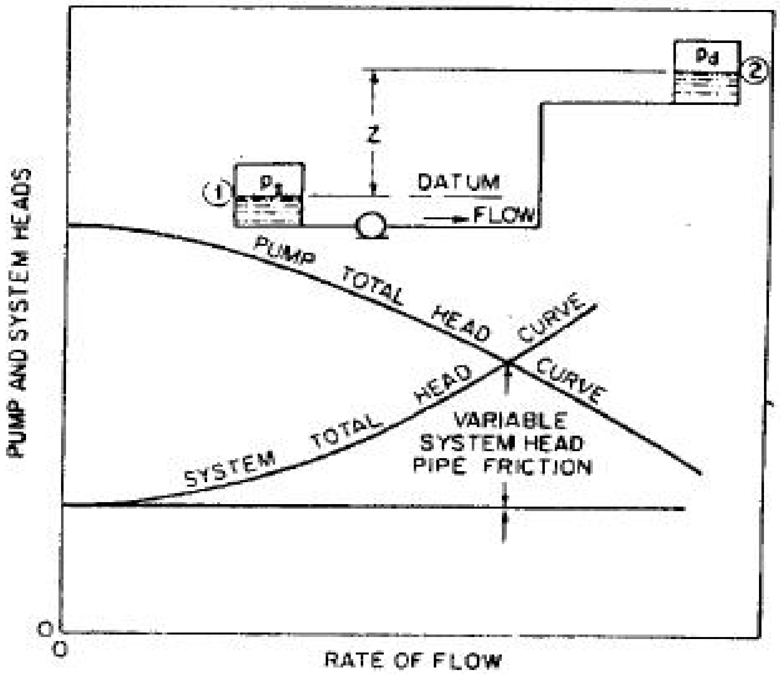


Fig (2-22): Head curve of a system consists of suction tank, receiving tank , pumps and pipes line connecting between them

Fig (2-23) shows total head curve of the system shown in Fig (2-24) consists of suction tank (D), pump, main pipeline (D) and different branch lines A, B and C, each ends with a receiving tank and intersects with pump total head curve.

In case of existence of difference in water level in intake (suction) sump, one system total head curve must be drawn at minimum water level and another one at maximum water level in the sump.

Fig (2-25) shows system total head curves at minimum and maximum water levels in the sump and their intersection with pump total head curve.

Note:

To calculate friction losses in the pipes and their components, and secondary losses of system components, refer to Egyptian Code concerning Design Criteria and Rules of Drinking Water and Sanitary Drainage Networks

2-3-9 Duty (Operating) Point

Each pump will have operating point B, the point of intersection of Q-H pump curve and system (pipe) curve HA. This point shall not change for the pump (and also for the flow Q and the head H) only if speed of rotation of the pump (n) or impeller diameter (D) is changed, or when changing system curve as shown in Fig (2-26).

2-3-10 Modified Head Curve

When designing a pumping station consists of number of pumps operating in parallel, pumps flow will be combined in common header or force main pipe, therefore pump head curve must be drawn again by subtracting head losses in suction and discharge of each pump at each flow rate. This curve is the modified head curve. Fig (2-27) shows the modified combination head curve using modified curves for each pump and the intersection point of modified combination head curve with system head curve is the total flow and total head of the operating pumps group.

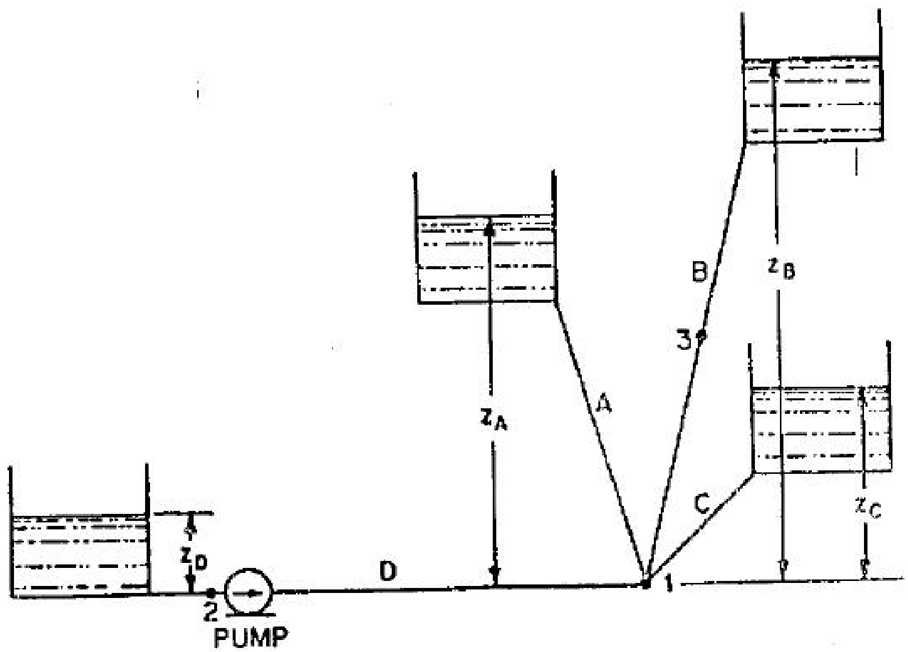


Fig (2-23): System consists of suction tank, main pipes line and different branch lines each of them ended to discharge tank

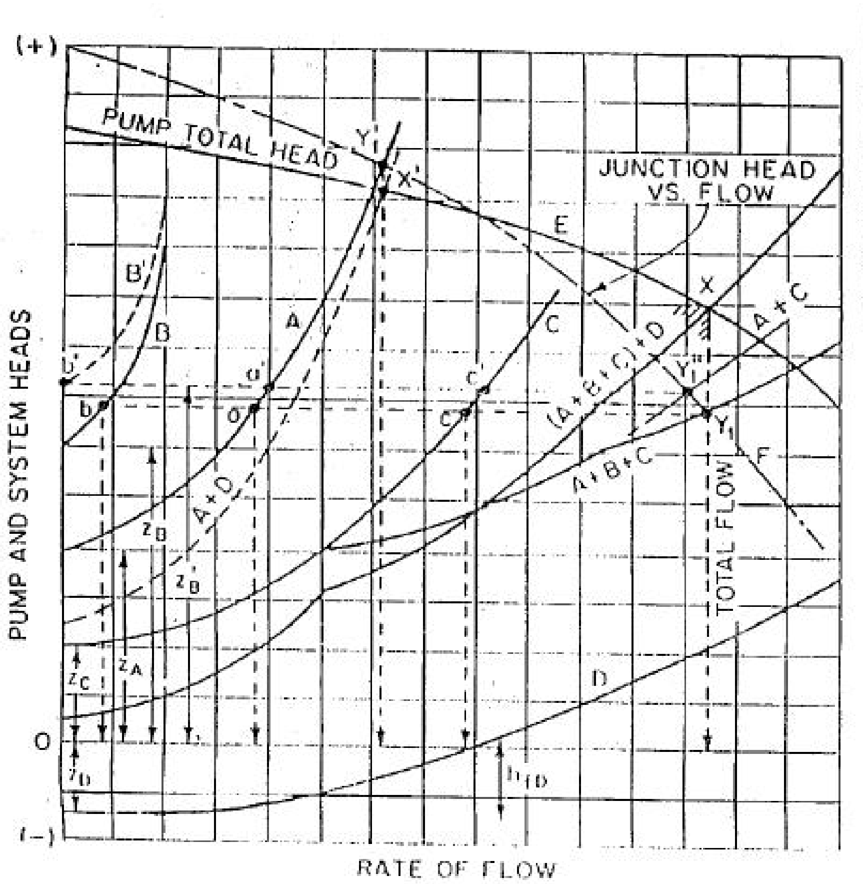


Fig (2-24): Head curve of the system illustrated in Fig (2-23)

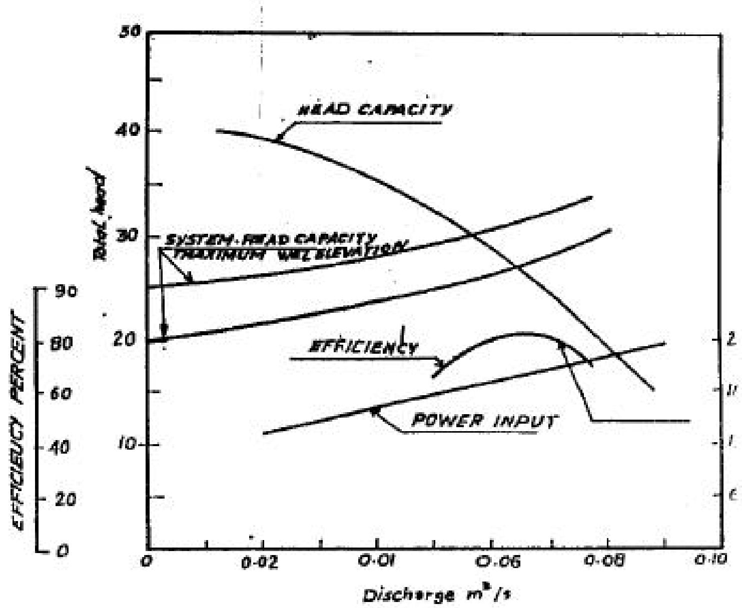


Fig (2-25): System Head Curves at minimum and maximum water level and their intersection with pump head curve

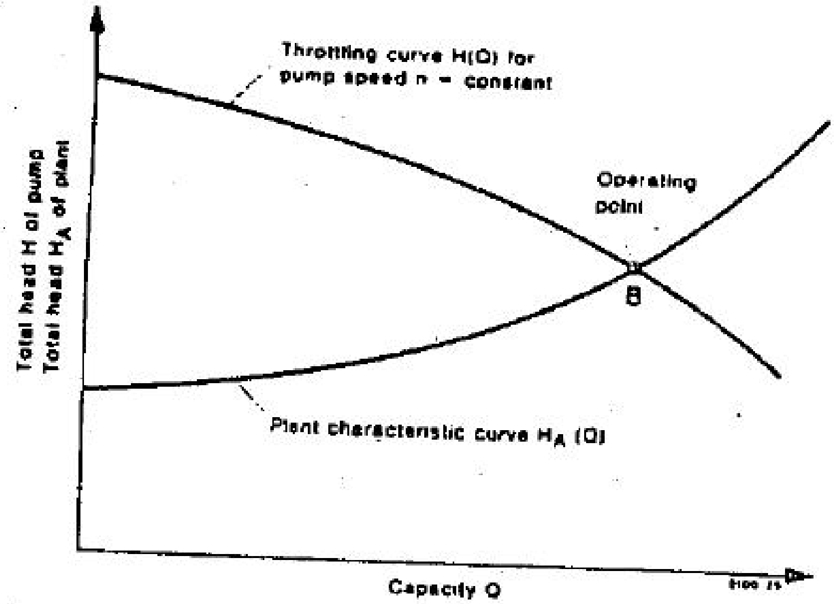


Fig (2-26): Intersection point of system head curve with throttling curve

2-3-11 Pump Combinations

Sets of pumps can be connected to operate together in parallel or in series:

In case of operation in parallel, the head is fixed and the flow is the sum of pump flows as illustrated in Fig (2-28).

$$H = H_1 = H_2 = H_3 = \ \ldots\ldots$$
$$Q = Q_1 + Q_2 + Q_3 = \ \ldots\ldots$$

In case of operation in series, the flow is fixed and the head is the sum of pump heads as illustrated in Fig (2-11).

$$Q = Q_1 = Q_2 = Q_3 = \ \ldots\ldots$$
$$H = H_1 + H_2 + H_3 = \ \ldots\ldots$$

If Q or H is different for the pumps, then:

Fig (2-30A) illustrates head curves of two individual and combined pumps in parallel and their point of intersection with system head curves of plant pipes (stable throttling curves).

Fig (2-30B) illustrates head curve of three equal pumps combined in parallel and their head curves.

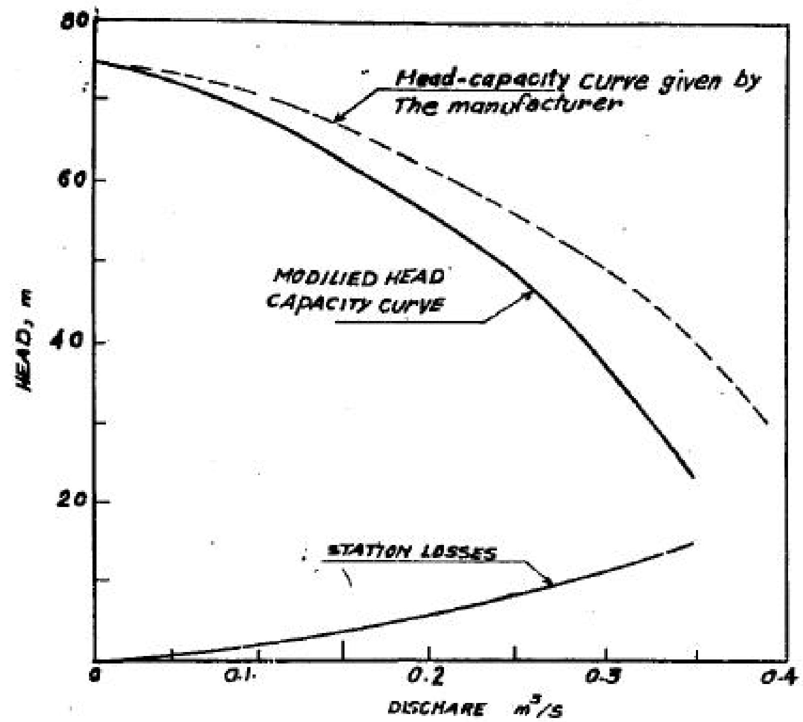


Fig (2-27): Modified head curve

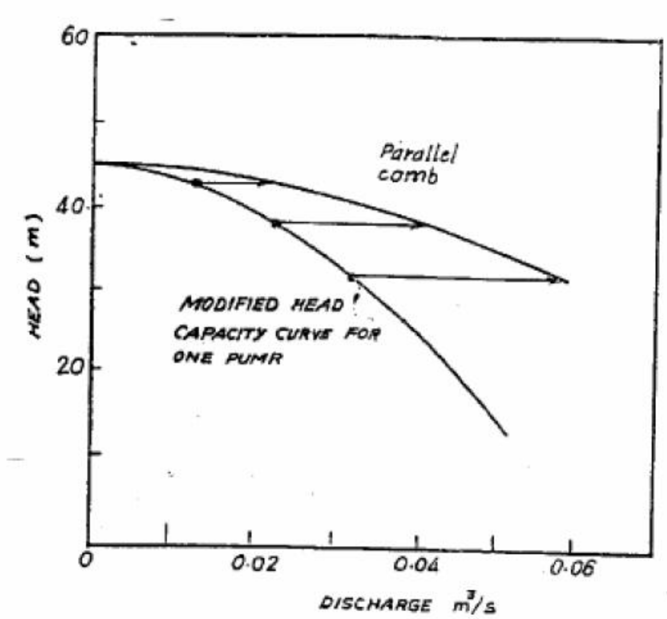


Fig (2-28): Operation in parallel curves

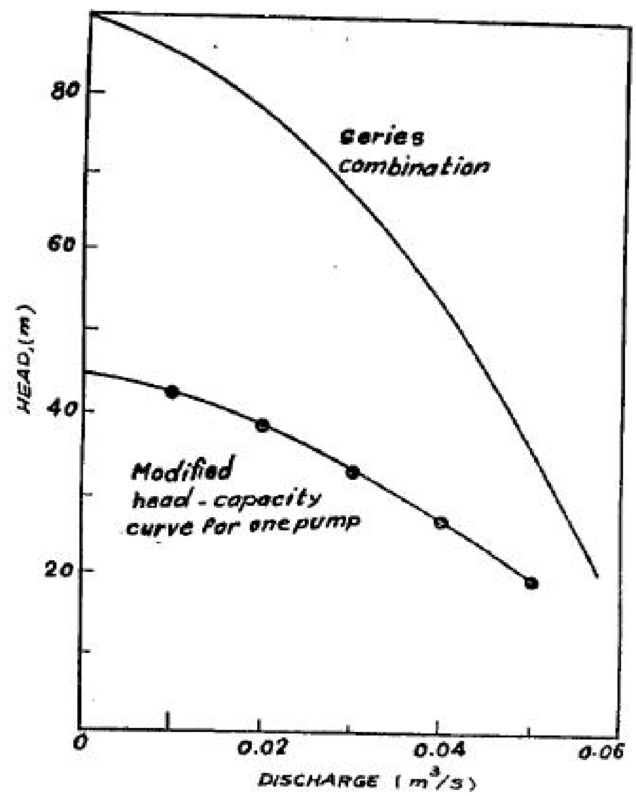


Fig (2-29): Operation in series curve

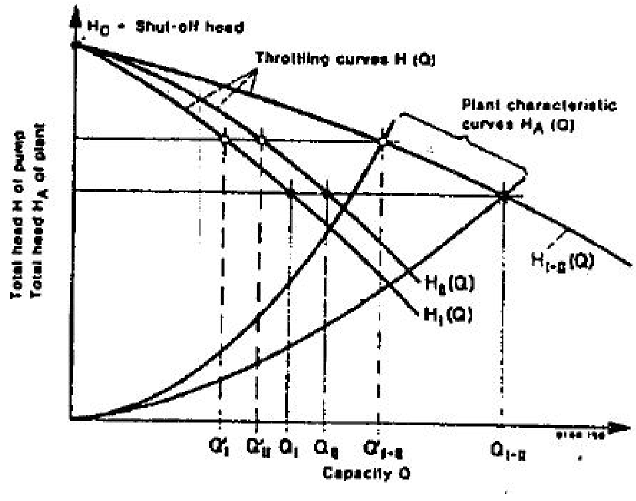


Fig (2-30A): Curve of operation of two combined pumps in parallel

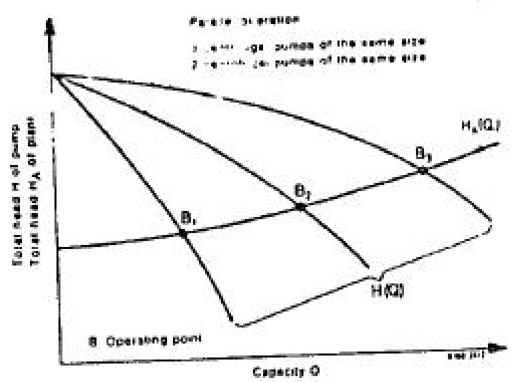


Fig (2-30B): Head curve of three pumps connected in parallel

Fig (2-31) illustrates head curves of two individual and combined pumps in parallel and their points of intersection with pipes system head curves (each has different shut-off point).

Fig (2-32) illustrates head curves of two individual and combined pumps in parallel and their points of intersection with pipes system head curves (unstable head curves and total head of each of them is equal).

Fig (2-33) illustrates the same head curves of two individual and combined pumps in parallel and their points of intersection with pipes system head curves (unstable head curves and head of each of them is different).

<u>Note:</u>

From the above figures, it is clear that:

When decreasing the total flow from Q_{1+2} to Q'_{1+2} the flow of each pump decreases also to Q'_I and Q'_2 on the curve of each of them.

Fig (2-34) illustrates head curves of two individual and combined pumps in series and their points of intersection with system head curve. In this curve, pump (2) does not give flow separately because of its maximum head at shut-off of discharge valve is less than static levels of the system.

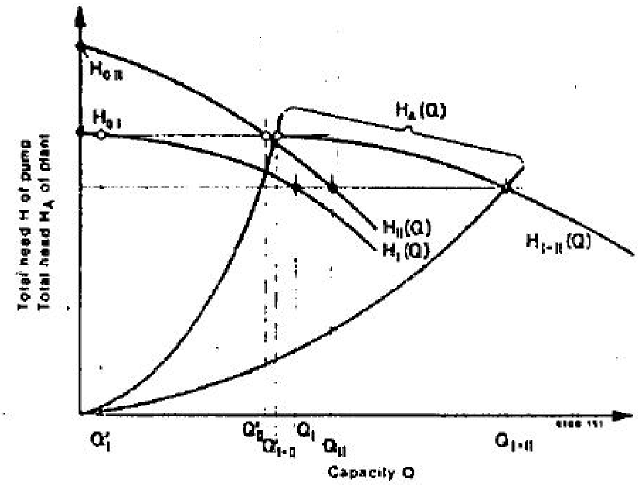


Fig (2-31): Head curve of two pumps individual and combined in parallel and have different heads

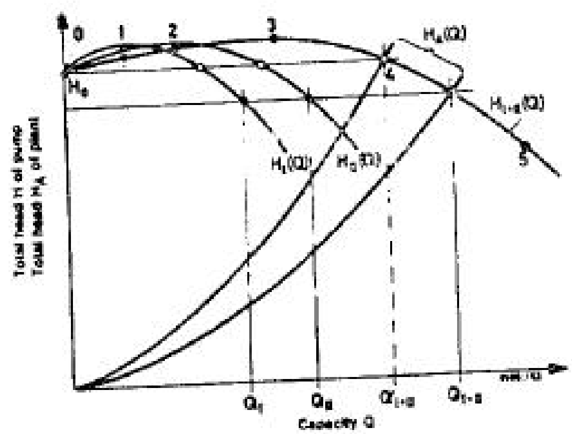


Fig (2-32): Unstable head curves of two different properties combined pumps in parallel

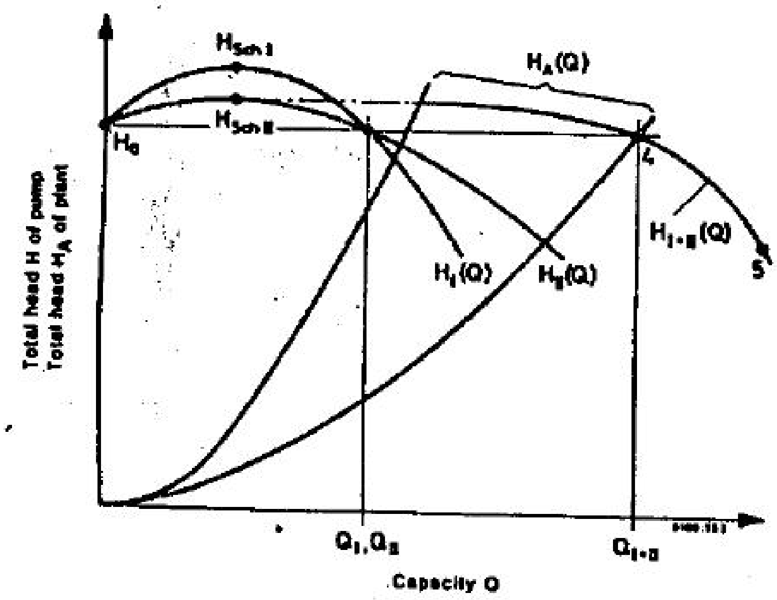


Fig (2-33): Head curves of two pumps combined in parallel have different properties and head of each pump is different

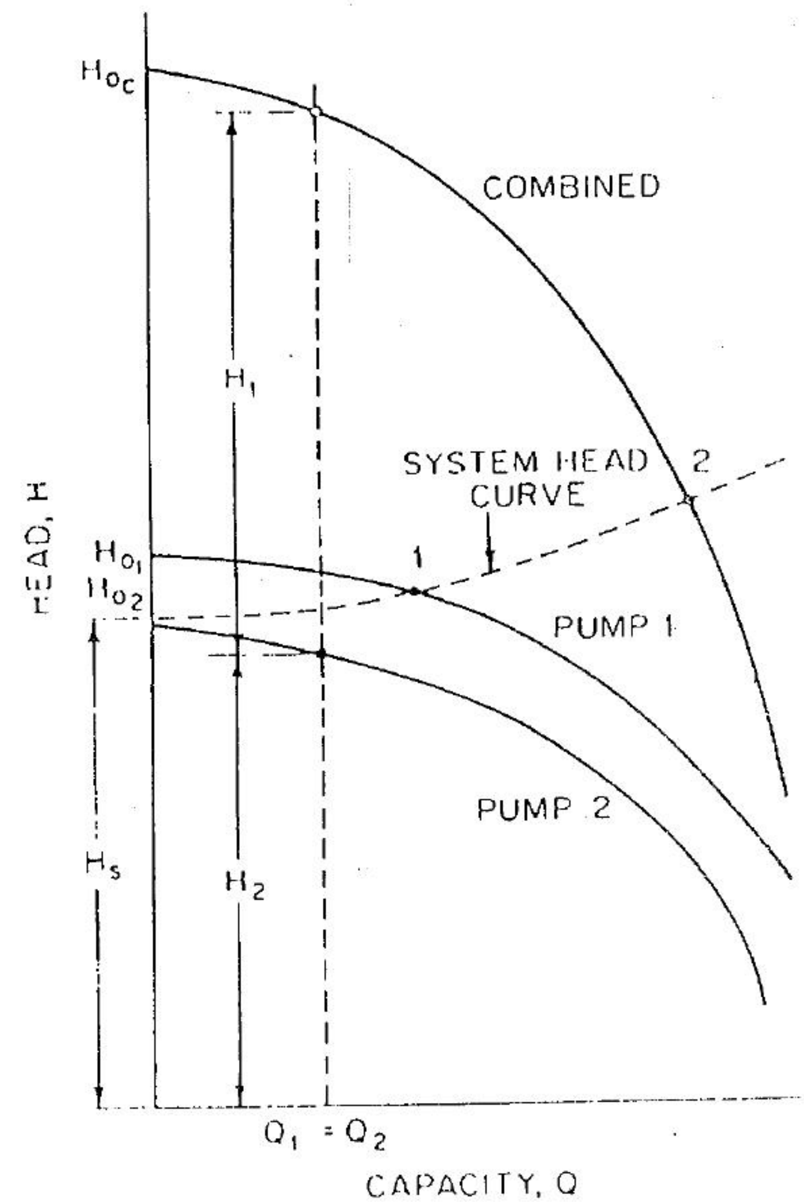


Fig (2-34): Head curves of two individual and combined pumps in series

2-3-12 Power

A- Water horse power of the pump:

$$\text{Water H.P} = \frac{W.Q.H}{75}$$

Where:

Q Flow (liter/sec)

H Total head (m)

W Liquid specific weight (kg/sec)

H.P Horse power equals to 75 kg. m/s

B- Shaft H.P:

$$\text{Shaft H.P} = \frac{\text{water H.P}}{\eta_H}$$

Where η_H = Pump hydraulic efficiency

C- Mechanical Power

$$\text{Mech . H.P} = \frac{\text{shaft H.P}}{\eta_m}$$

Where η_m = Mechanical efficiency for transferring through pump bearings.

D- Required electrical power:

$$\text{Ind.Elect. H.P} = \frac{\text{Mech. H.P}}{\eta_{mot}} \times 0.746 \text{ kwl}$$

Where mot = Electrical motor efficiency

0.746 for transformation the units from (horse power) to (KW)

2-3-13 Efficiency

Pump total efficiency =

$$= \frac{\text{Water H.P}}{\text{Ind.Elect H.P}}$$

$$= \frac{\text{Water H.P}}{(\text{Mech.H.P}/\eta_{mot})}$$

$$= \frac{\text{Water H.P}}{(\text{Shaft.H.P}/\eta m)/\eta_{mot}}$$

$$= \frac{\text{Water H.P}}{(\text{Water H.P}/\eta_H)/\eta m/\eta_{mot}}$$

$$\eta_{Total} = \eta_{mot} \;.\; \eta m \,.\, \eta H$$

- Total efficiency of the pumps operating in parallel

$$\eta_o = \frac{W.H.\Sigma Q}{75\ \Sigma P}$$

Where:

$\Sigma\ Q$= Sum of pumps flow (liter/sec)

$\Sigma\ P$ = Sum of powers given for all pumps (H.P)

- Total efficiency of the pumps operating in parallel

$$\eta_o = \frac{W.\Sigma\ Q.H}{75\ .\ \Sigma\ P}$$

Where:

$\sum H$ = Sum of pumps head in meter

2-3-14 Control of Centrifugal Pump

Pump and the system are the main factors in meeting flow and head requirements necessary from the plant. To modify the flow and head, any of them must be controlled.

- Control of the system is performed by control of plant discharge valves throttle range to the external network. Figures (2-35, 2-36) illustrate pump Q-H curve and the different system curve resulted from the control of throttle degree of discharge valves.

Fig (2-37) illustrates change of the operating point with the change of pump speed.

- Pump control is performed by one of three methods:

1. Changing inclination angle of impeller blade (by the manufacturer)

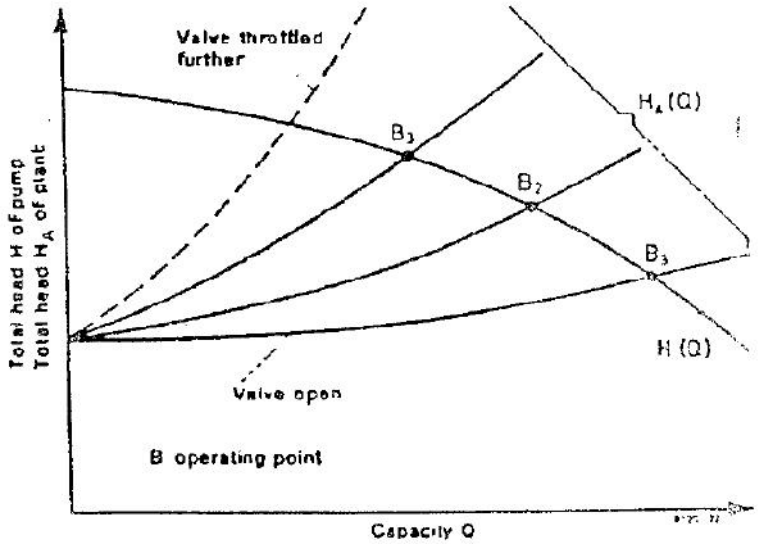


Fig (2-35): H.Q pump head curve according control in discharge valve throttle

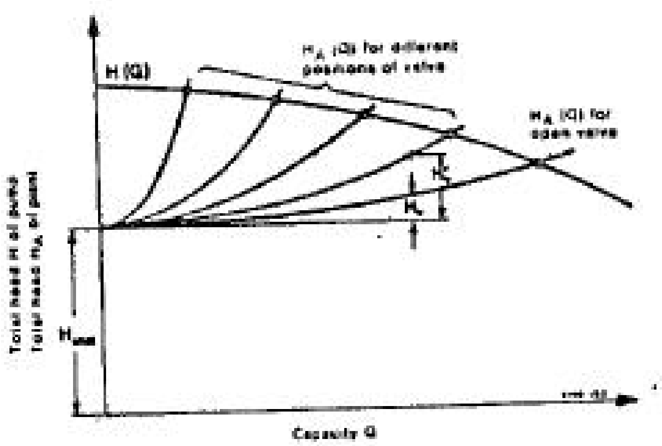


Fig (2-36): pump head curve according control in discharge valve throttle

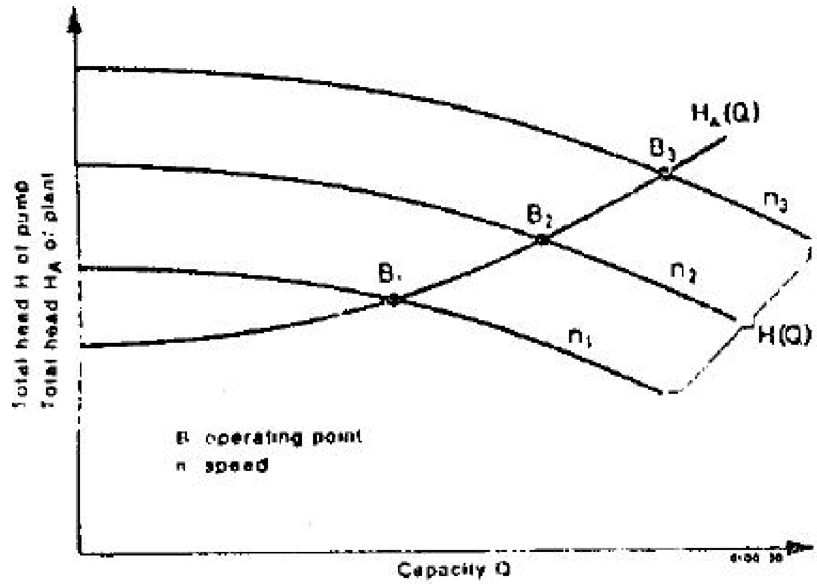


Fig (2-37): Change of operating point by change of pump speed

2. Modification of impeller position on the shaft or addition of sealed cover at pump screw enclosure inlets (by the manufacturer).
3. Decreasing impeller diameter by trimming (commonly used in the plants)

Fig (2-38) illustrates modification of pump head curves H-Q and P-Q as a result of changing impeller blade inclination angle.

Fig (2-39) illustrates modification of pump head curves H-Q and P-Q as a result of changing impeller position on the shaft or addition of sealed cover at screw enclosure inlet.

Fig (2-40) illustrates modification of pump head curves H-Q and P-Q as a result of decrease impeller diameter by trimming and their points of intersection with system head curve.

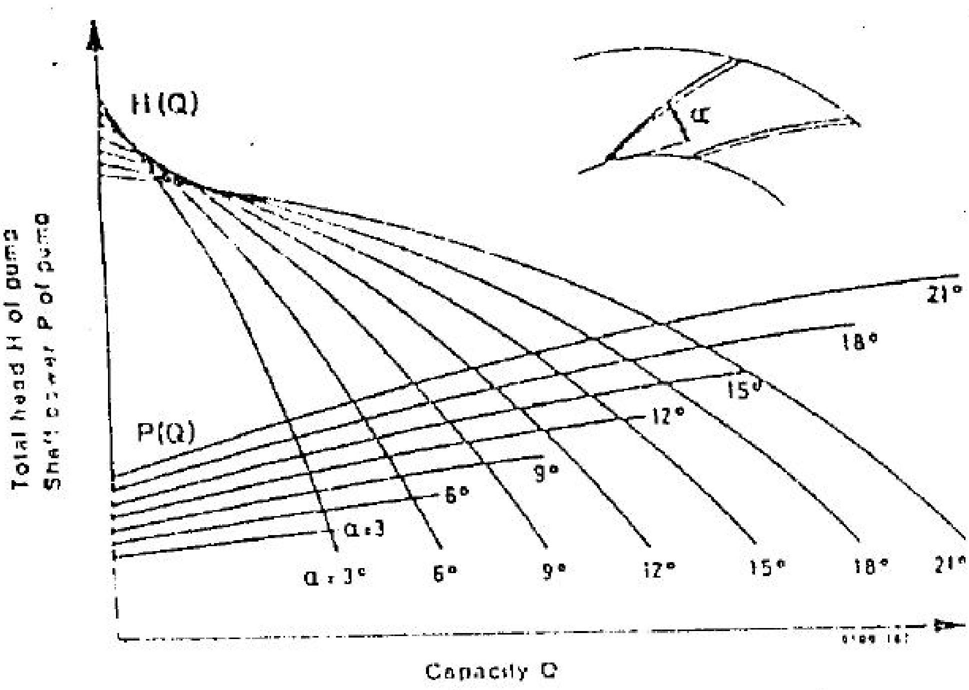


Fig (2-38): Change of characteristic curves by changing blade inclination angle

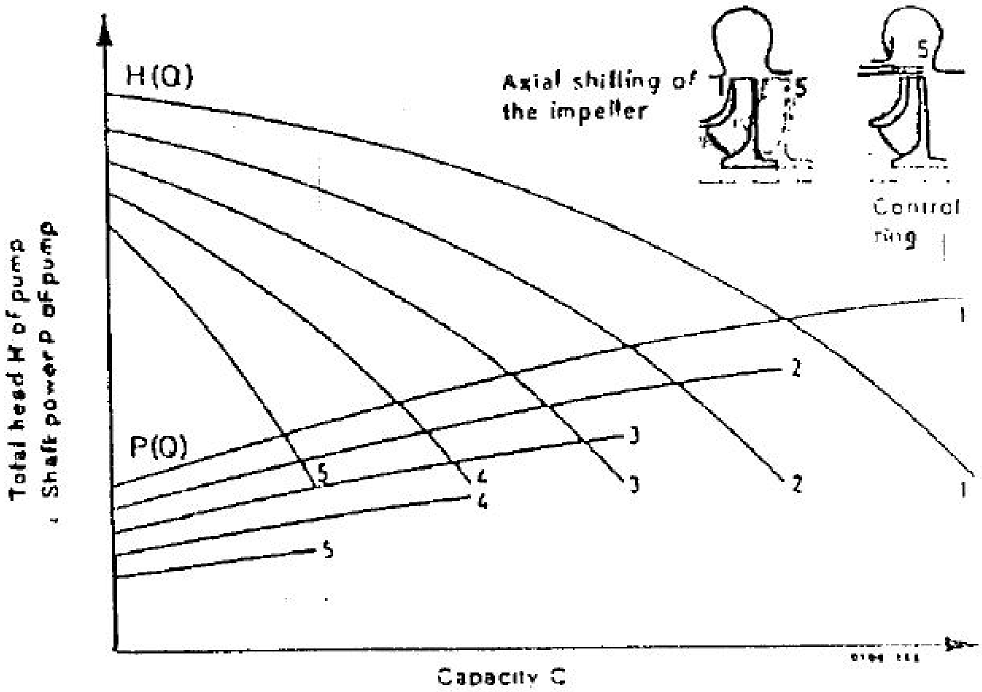


Fig (2-39): Change of characteristic curves as a result of changing impeller position on the shaft or addition of sealed cover at screw enclosure inlet

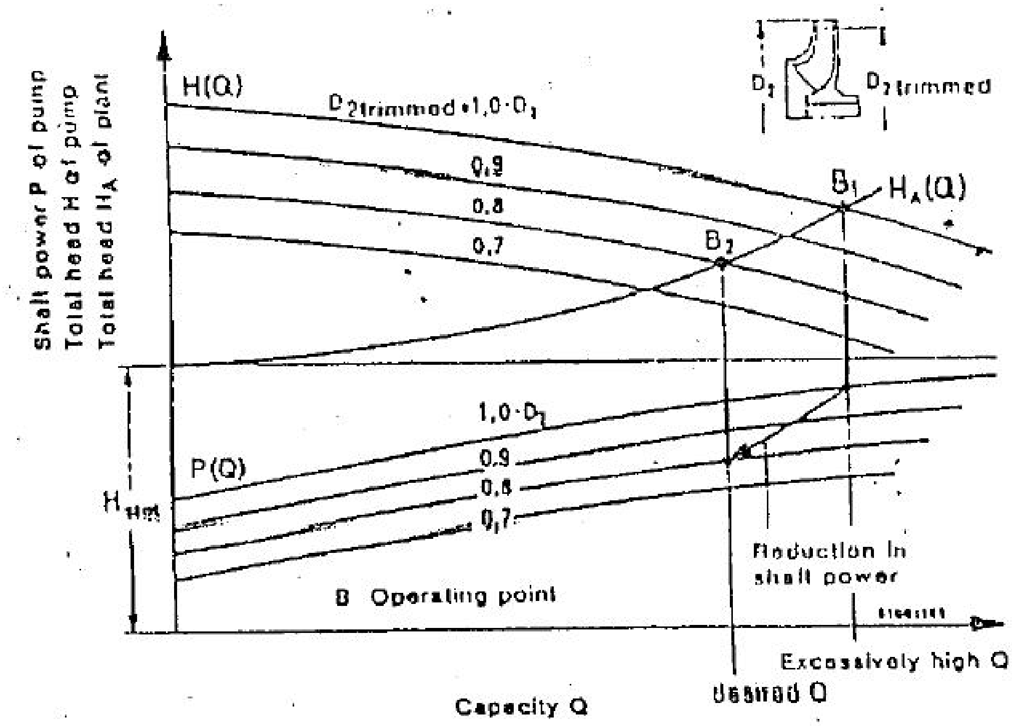


Fig (2-40): Change of characteristic curves as a result of changing impeller diameter by trimming

2-3-15 Pumps Priming

1. Any centrifugal pump will not operate unless its screw enclosure and suction pipe are filled with the liquid required to be pumped.
2. Pumps must be installed such that its axis level is less than water level in the sump to avoid occurrence of pressure less than the atmospheric pressure leads to air leakage or emission of the dissolved gases to the suction pipe forming accumulation of air bubbles causing disturbance and decrease in pumps flow and efficiency.
3. In case of failure to fulfill the previous condition (2), the difference between pumps axis level and minimum water level in the sump must not less than the value H_s as in the following equation:

$$H_s = H_A - (H_v + h_{vap} + H_f + H_m)$$

Where:

H_s Difference between pumps axis level and minimum water level in the sump (Static suction head) in meter.

H_A Atmospheric pressure (10.33 m)

H_V Vel. Head

h_{vap} Vapor Head

H_F Friction head loss in suction pipe (m)

H_m Secondary losses in suction pipe (m)

4. In case of failure to fulfill the previous condition (3), pump will be primed mechanically as follows:-

2-3-16Priming Means

2-3-16-1 Ejector

It operates by water, air or vapor to suck and remove the air completely from pump case and suction pipe for continuous exit of water from ejector discharge, then the pump is operated after close the ejector connection valve firmly.

2-3-16-2 Foot Valve

Is a kind of non-return (check) valve installed at the beginning of the suction pipe after the screen directly and closed automatically to prevent escape of water in case of sudden stop of the pump. Top of the pump is provided with air cock opens during filling of the pump with water to enable exit of water.

Due to impossibility of full close of the check valve, this will lead to leakage of water and must fill pump case and suction pipe to compensate the losses before pump operation. Therefore, periodic inspection must be performed for this valve to ensure its full close and prevent leakage of water.

Existence of this valve causes loss in pressure and undesirable to be used.

2-3-16-3 Central Priming System

This system is used to prime pumps automatically, individually or combined, by air evacuation system from a valve at the top of the screw case of each pump and by using evacuating pump.

2-3-17 Evacuating Pump

This pump is used if the previous priming means are not available. It is preferred to use the wet type because it will not be damaged if it is subjected to water.

Evacuating pump is selected according to required priming time and maximum suction head by using the following equation:

$$T = \frac{V}{Q_s} \cdot f$$

Where:

T Priming time (s)

V Air volume in the pump, vertical and horizontal suction pipe (m^3)

Q_s Priming pump capacity (m^3/s)

f Suction factor according to the following table:

Suction head (m)	0	1	2	3	4	5	6	7	8
Vertical line factor f	0.087	0.093	0.099	0.104	0.11	0.118	0.125	0.134	0.143
Horizontal line factor f	0.087	0.097	0.107	0.119	0.132	0.148	0.168	0.19	0.23

2-3-18 Types of the used pumps

2-3-18-1 Vertical Pumps

Vertical pumps are prepared for submersible operation in the wet sump; it can also be used in dry sump, where it is similar in construction as the horizontal pumps but it is lower in economic cost.

Vertical pumps are designed and produced according to the required services and conditions of use in the wet well as follows:

1. Vertical turbine pumps.
2. Propeller pumps
3. Volute pumps

In addition to other types for other uses.

2-3-18-2 Vertical Turbine Pumps

These pumps are used to lift water from the wells and are called deep well pumps with capacity limited by well volume and safe suction rate without decrease of water level more than the flooded limit required for the pump. They contain many stages of impellers to fulfill design flows for these pumps that reach to 700 liter/s and head reaches to 300 water meter.

This type of pumps is used in other works such as irrigation, industrial purposes, cooling, air conditioning, desalination plants and dewatering processes.

These pumps are provided with drive shaft for vertical motion, bell mouth and screen. Pump motor is provided with bearings withstand drive shaft weight and pump impellers safely.

To avoid the difficulties of the required shaft length, submersible pumps are used, where the motor is installed under the pump in the well and directly coupled with the pump and the entire unit is submersed in the well.

2-3-18-3 Propeller Pumps

Axial propeller pumps are used in sumps and open houses and are mostly short with low pressure. When the head is increased, mixed flow impellers are used.

2-3-18-4 Volute Pumps

These pumps are used suspended for sludge lift.

2-3-18-5 Submersible Pumps

These pumps are used for dewatering of water accumulated in the sumps and houses and are installed at the bottom of the sump or suspended on house floor (sump roof). They are driven by electrical motor submersed with it. They are controlled automatically by float switch. This pump contains one stage or many stages and has wide range of specific speed and flow.

2-4 Flash Mixer

The rapid (Flash) fixer is used in rapid mixing and equal distribution of flocculants in the raw water in a very short time does not exceed few seconds.

- It consists of electrical motor, gearbox, stainless steel shaft and flat bladed propeller made from ductile iron or stainless steel.
- Flash mixing is done usually in a tank provides stay period ranges from 30 to 60 seconds.
- The flash mixer is equipped with mechanical mixer consists of flat bladed propeller provides velocity gradient ranges from 300 to 700 sec^{-1}
- Mixer speed of rotation ranges from 60 to 120 rpm
- Propeller diameter ranges from 1/3 to 1/2 tank diameter.
- Propeller depth reaches to 2/3 water depth in the tank.
- Reynolds number must be revised to fulfill the disturbed flow (Turb. Flow)

$$R_n = \frac{d^2 \rho n}{\mu}$$

Where:

Rn = Reynolds number

d = propeller diam. in (meters)

ρ= mass density of water (1000 kg/m3)

n = Revs/sec For the propeller

μ= Dynamic Viscosity = 1.15×10^{-3} kg / m. sec. at 15 °C

The required theoretical power calculation must be revised

$P = k \rho n^3 d^5$ Where K = 1

Velocity gradient calculation must be revised

$G = (P / \mu V)^{1/2}$

G = vel. gradient

P = theoretical power in J/sec (w)

V = Tank volume (m^3)

2-5 Flocculation

- Flocculation is the process comes after flash mixing process for the purpose of collection of small flocculated turbidity particles to form larger particles of heavier weight easy to be disposed by sedimentation and filtration. This process is performed by slow mixing, where it facilitates contact between small particles to be collected and stuck with each other forming flocs.
- Mixing inside flocculation is performed either mechanically by horizontal or vertical mixers, or hydraulically by passing in baffled channels.
- Stay period inside flocculation tanks or through baffled channels ranges from 20 to 30 minutes in case of direct filtration, and from 20 to 40 minutes in case of using conventional sedimentation and filtration system.

- The mechanical mixers are either horizontal in case of using relatively slow sedimentation and filtration processes, where it needs to remove greater percentage of solids in the sedimentation tanks, or vertical, where it is used in case of using high filtration rates, where the flocs are passed inside filtration medium.

- The mechanical mixers consist of electrical motor and a gearbox (variable speed) to drive set of wooden pedals with rotational speed ranges from 0.1 to 0.6 rpm.

- Flocculation tanks for horizontal mixers are rectangular and for vertical mixers is square or circular shape.

- Pedals are designed in a way that achieve velocity gradient ranges from 8 to 1 sec^{-1} in case of vertical pedals and from 3 to 5 sec^{-1} in case of horizontal pedals, and is calculated as follow:

$G = (P / \mu V)$

P = power input J/sec (watt)

V = volume of water in tank m^3

μ = absolute viscosity= 1×10^{-3} kg/m. sec

$$P = \frac{C_d A \rho (V_r)^3}{2}$$

$$G = C_d\ A^3_r\ ./\ 2\ k\ V)^{1/2}$$

Where:

C_d = drag coeff of the paddle depends on shape of Paddle = 1.0 for flat and more for profile angle and to be 1.8 .

A = area of the paddle m^2

V_r = relative velocity of paddle to water (0.45 -0.7 m/s)

k = kinematic viscosity of water

= 1.14×10^{-3} at 15 °C & $\rho = 1000$ kg/m³.

= 0.89×10^{-3} at 25 °C & $\rho = 995$ kg/m³.

V = volume of water in tank (m^3)

Baffled channels are designed in a way that water velocity inside it ranges from 0.15 to 0.45 m/s and to achieve velocity gradient G ranges from 2 to 35 sec^{-1} with horizontal or vertical flow. It is calculated as follows:

$$G = \sqrt{g \rho h / \mu t}$$

Where:

g = gravity constant = 9.81 m/sec

ρ = mass density = 1000 kg/m³

h = head loss (m)

μ = absolute viscosity = [illegible] kg/m sec

t = retention time (sec)

$$h = L V^2 / C^2 R$$

Where:

L = length of mixing channel (m)

c = chezy coefficient

R = Hydraulic radius

V = mean flow velocity (m/sec)

In case of water rotation 180° inside square section pipe, the following equation can be used:

$$h = 3.2 \, (v^2 / 2g)$$

2-6 Clarifiers

2-6-1 Process description

Clarification is the process comes after flocculation process for the purpose of removing solids which exist in the water that can be settled by gravity, including sand, silt, chemical sediments and flocs. This process is performed in settlers or clarifiers.

Tanks are specially designed for this process called sedimentation tanks or clarifiers of rectangular, square or circular shapes, and the most common types are the rectangular ones, where water flows parallel to length of the tank and is called straight lines flow. In the circular tanks, water flow in radial path, i.e. from the center to the outer circumstance.

2-6-2 Sludge removal equipments

The settled layer of sludge is removed regularly from the clarifiers to avoid its suspension again and cause unpleasant taste and odors. This can be done manually (by opening valves in series form the bottom) or by mechanical equipments, such as scrapers installed on the bridges or scrapers provided with steel track, rubber, galvanized iron or plastic scraper.

2-7 Filters Building

2-7-1 Process description

It is a physical and chemical process for the purpose of removing organic or inorganic suspended and alluvial materials. In this process it is usually used sand particles of suitable size, through it the clarified water is passing with suitable velocity to achieve this process.

2-7-2 Types and design criteria of filters

2-7-2-1 Slow sand filters

The filter is composed of large tank made from bricks or concrete and contains layer of sand over a layer of graded size gravels. Under gravels there is a grid of perforated pipes laid on the floor of filter. It is used for filtration of water of simple turbidity that does not exceed 20 NTU, where 90% of it is removed. It is recommended to be used in large cities, because it requires relatively large areas.

- Filtration rate : 3-5 m^3 / m^2 / Day
- Filter Area : 500- 1000 m^2 for small plants, and reaches for large plants to 400- 5000 m^2.
- Sand layer thickness : 70-90 cm
- Gravel layer thickness : 30-60 cm
- Under the filter : Blanked clay blocks, cement perforated pipes or perforated plastic pipes (water velocity inside the pipes must not exceed 0.6 m/s)
- Water Height : 1.2 – 1.5 m (Over sand surface)
- Filtration period : From 1 to 2 months
- Filter regulator : It is not required and it is enough to adjust the heir manually to control the filtration.
- Sand specifications : Strong coherent granules, contains a high proportion of quartz, free of impurities and clay and non-fragile.

- Active size : 0.25 to 0.35 mm
- Regulation factor : 1.7 to 2.00
- Specific weight : 2.55 – 2.65
- Dissolution in hydraulic acid : Does not exceed 3%
- Wear by friction : Does not exceed 3%
- Sand grain diameter : Does not exceed 2 mm
- Gravel specifications : Strong spherical regular shape, pure and free of impurities and clay.

  - Grain diameter ranges from 3 mm to 60 mm laid in four layers, the larger down and the smaller up.
- Filter cleaning : Manually to scrape off 7 cm of the upper layer of sand at successive periods until sand layer reaches 40 cm.

  - The removed layer of sand is cleaned in special machines and can be reused by laying it upper filter surface.

2-7-2-2 Rapid Sand Filter

The filter is composed of concrete tank contains layer of sand of certain size over a layer of graded size gravels. Under gravels there is a grid of perforated pipes distributed regularly in all filter points, or perforated concrete tiles provided with plastic screens distributed regularly in all filter points to collect the treated water in a water storage tank. It is used for filtration of pre-treated water by coagulants (alum).

Sand is washed by passing and pushing the treated water in a direction opposite to the direction of filtration after loosing sand layer either by compressed air or surface washing.

-	Filtration rate	: 120-200 m^3 / m^2 / Day
-	Filter Area	: Does not exceed 150 m^2
-	Sand layer thickness	: 50-70 cm
-	Gravel layer thickness	: 30-60 cm (Sometimes it is used one layer of sand of thickness ranges from 1.0 to 1.2 m in case of using screens "Nozzles")
-	Drainage system	: Under-drainage system
-	Concrete blocks	: In the shape of letter N or M with side gaps, perforated concrete, plastic or concrete tiles provided with the screens.
-	Water Height	: 1 m (Over sand surface)
-	Filtration period	: From 12 to 36 months, taking into consideration maximum allowable pressure loss inside the filter according the type.
-	Sand specifications	: Strong coherent granules, contains a high proportion of quartz, free of impurities and clay and non-fragile.
-	Washing water rate	15-35 m^3 / m^2 / h

- Washing air rate : 35-75 m^3 / m^2 / h
- Washing air pressure : 0.3-0.5 kg / cm^2
- Surface washing water rate : 7-10 m^3 / m^2 / h (fixed screens "Nozzles")

  : 2-3.5 m^3 / m^2 / h (rotating screens" Nozzles")
- Water velocity in pipes
- Inlet : 0.5 – 0.75 m/s, average = 0.6 m/s
- Filtration : 0.6 – 1.5 m/s, average = 1 m/s
- Washing : 1.5 – 3 m/s, average = 1 m/s (for main)

  : 2 – 3.5 m/s, average = 2.5 m/s (for branch)
- Sand specifications : Strong coherent granules, contains a high proportion of quartz, free of impurities and clay and non-fragile.
- Active size : 0.6 to 0.7 mm
- Regulation factor : 1.35 to 1.50
- Specific weight : 2.55 – 2.65
- Dissolution in hydraulic acid : Does not exceed 3.5%
- Wear by friction : Does not exceed 3%
- Sand grain diameter : Does not exceed 2 mm
- Gravel specifications : Strong spherical regular shape, pure and free of impurities and clay.

  - Grain diameter ranges from 2 mm to 20/25 mm laid in four layers, the larger down and the smaller up as follows:

- **A- Concrete blocks: -**

- Fourth : Thickness 100 mm for size 2 – 3.5 mm
- Third : Thickness 100 mm for size 3.5 – 7 mm
- Second : Thickness 150 mm for size 7 – 13 mm
- First : Thickness 150 mm for size 13 – 20 mm
- **B- Perforated Pipes: -**
- Fourth : Thickness 100 mm for size 2 – 5 mm
- Third : Thickness 100 mm for size 5 – 9 mm
- Second : Thickness 150 mm for size 9 – 16 mm
- First : Thickness 150 mm for size 16 – 25 mm

Specifications of under-drainage system

- **A- Perforated Pipes**
    - Anti-rust and withstand pressure.
    - Regular holes in diameter and angle
    - Hole diameter ranges from 7.5 to 20 mm wavy down with an angle of 30° with the lower trace.
    - Pipe length: 60 times the diameter
    - Distance between pipes: Not less than 30 cm

- **B- Screens**
    - Anti-rust and withstand pressure.
    - Ratio of screens nozzles: active filter area = 0.2-1.5%

2-7-2-3 Pressure Filters

This filter is similar to the rapid filter consists of sand, gravel and lower pipes grid, and differs in that it is inside closed steel cylinder and the water is filtered under pressure exceeds 2 bar. It is characterized by small size and needs area smaller than the rapid filter. It is used in compact units and swimming pools.

- The filters are vertical or horizontal in terms of cylindrical structure axis of the filter, but water flow in both cases is vertical from up to down and is washed in a direction opposite to direction of filtration.
- It is used in filtration of pre-treated water by coagulants.

Filtration rate	: 170-480 m^3 / m^2 / Day
Filter Dimensions	: Diameter ranges from 0.50 to 3.60 m
	: Length: ranges from 1.0 to 7.5 m
Sand layer thickness	: Differs according to volume and length of the filter
Gravel layer thickness	: Differs according to volume and length of the filter
	(Sometimes it is added upper layer of Anthracite Coal over the sand)
- Drainage system	: Under-drainage system. It is made from perforated pipes or pipes provided with screens (Nozzles) or Intranite tiles provided with screens (Nozzles).

- Filtration period : 12-36 hours
- Washing water rate 15-25 m^3 / m^2 / h
- Washing air rate : 50 m^3 / m^2 / h
- Sand specifications : Similar to rapid sand filter (active size 0.7-1.35 mm)
- Gravel specifications : Similar to rapid sand filter.
- Under filter specifications : Similar to rapid sand filter for pipes and screens (Nozzles)

2-7-2-4 Filter washing pumps

Vertical or horizontal centrifugal pumps are used in filter backwash system for rapid sand filters and pressure filters. They are similar to raw water pumps in terms of types, specifications and performance.

Pump flow is determined according to the selected wash rate which ranges from 15 to 35 m^3 / m^2 / h for rapid sand filters, and 15-25 m^3 / m^2 / h for pressure filters according to type and system of operation of any of them multiplied by sand area inside the filter.

Dynamic head of the pump is determined by calculating total static head between minimum water level in the ground tank under the filters and water level over the heir in washing channel (or overflow pipe in pressure filters) added to it suction, discharge and velocity losses in distribution pipes and also in lateral pipes or nozzles in addition to losses of passing inside filtration medium.

2-7-2-5 Compressed Air System

Introduction:

Compressed air is used in drinking water purification plants in one stage of filters washing that requires compressed air rate ranges from 35 to 75 m^3 / m^2 / h and pressure ranges form 0.3-0.5 kg/cm^2 and velocity ranges from 10-25 m/s in filter wash air inlet pipes.

Air system components:

Air system in drinking water purification plants consists of compressors and air collection tanks. In the modern systems, blowers are used without tanks and air pipes.

The required flow:

The required air flow per hour is determined by calculating surface area of the filters require to be washed using compressed air rate according to filters design.

Pressure:

Air pressure required for washing works ranges from 0.3 to 0.5 kg/cm^2. The pressure must be continuous and regular. Air pressure in the air tanks adjacent to compressors must be more than the required pressure for washing works by 0.2 kg/cm^2.

Pressure drop in distribution pipes

The graph in Fig (2-41) is used for calculation of pressure drop in pipes due to friction with pipes ranges from ½" (12.5 mm) to 12" (300 mm) with pressure 400 Lb / square inch = 28 kg/cm^2.

Pipes and components

Pipes and their components are started from the compressor or blower to compressed air tanks then to the filters passing in trenches under roads (installed on trench floor or wall) or on any wall to location of use.

- Pipes are made form stainless steel or UPVC to avoid wear by chemicals.

Pipes Design Rules

The following must be taken into consideration in pipes design:

1. Use loop from the pipes to ensure continuous use without interruption due to maintenance works.
2. Air outlets are taken over the pipes and near from usage locations.
3. Pressure between the compressor and location of use must not decrease more than 10% of the original pressure. Therefore, pipes must be selected with diameter greater than design diameter.
4. Pipeline length is increased due to existence of elbows according to turning diameter of the elbow as follows:

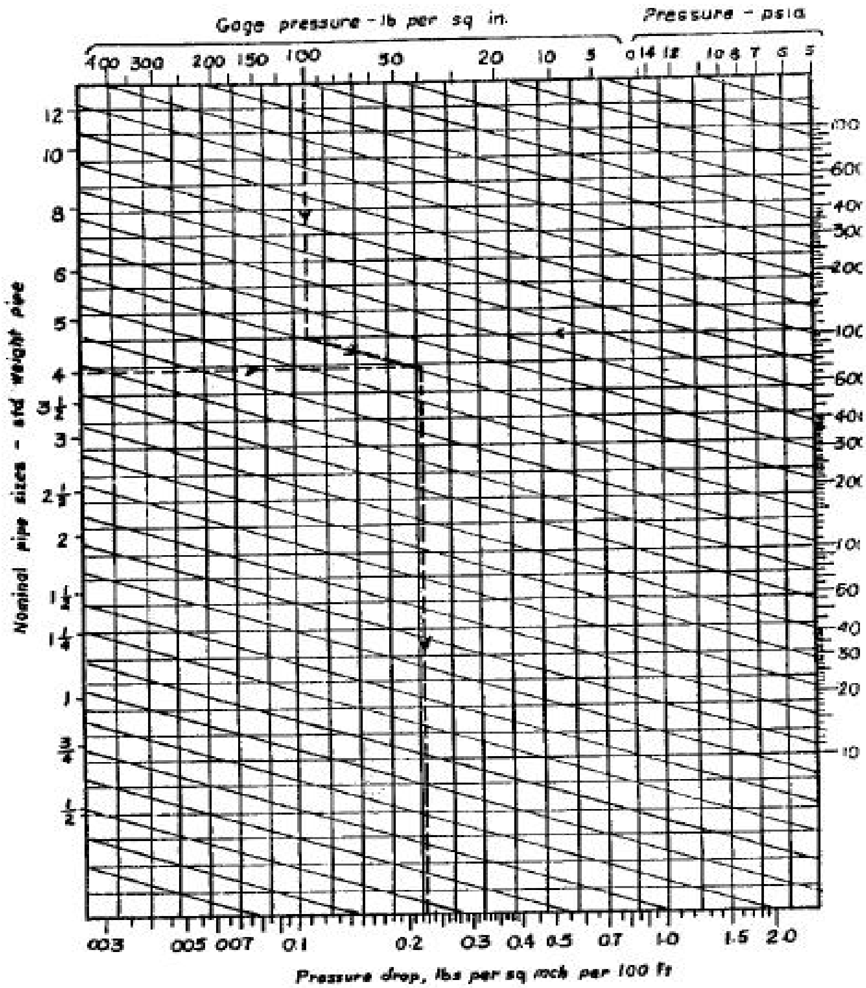


Fig (2-41): Pressure drop in operation pipes

Elbow Turning Diameter	Pipeline length increase
1 diameter of pipeline	17.5 line diameter
1.5 diameter of pipeline	10.4 line diameter
2 diameter of pipeline	9 line diameter
2 diameter of pipeline	8.2 line diameter

Pipe Thickness:

Steel pipe thickness is calculated from the equation:

$$t_m = \frac{P\ D}{2\ S_E} + A$$

Where:

t_m = Minimum calculated thickness (inch)

P = Design pressure (lb / sq in)

D = Outer diameter (inch)

S_E = Allowed stress (ranges from 16000- 13600 lb / sq in)

A = Total area required for threading 12% and for wear and corrosion ad 1/8"

Vibrations insulation

Pipes must be insulated from the vibrations generated from the compressor or blower by connecting them with flexible joint.

Expansion and flexibility:

To avoid expansion works due to temperature rise, expansion value must be taken into consideration or to install expansion joint on the pipes.

Expansion value is taken for each 11°C and for each 30 m as follows:

Stainless Steel = 14 mm

PVC = 45 mm

Therefore, guides must be installed for open pipes for easy motion due to expansion.

Supporting of Pipes

Pipes must be fixed by supports with certain diameters at distances as follows:

Pipe Diameter	Minimum distance between supports	Minimum diameter of the support
1 ½ " and less (40mm)	6" (2 m)	3/8" (10 mm)
2"-6" (50-150 mm)	8" (2.5 m)	½" (12 mm)
8"-12" (200-300 mm)	10" (3 m)	5/8" (15 mm)

The following must be taken into consideration when performing supporting works:

1. Avoid any stress on the valves, pieces or equipments.
2. Supporting will be at each change in direction, level or adjacent to flexible joint.
3. Do not put supports at the areas specified for machines or in the path of crane beam.

Pipe connections:

Pipes are connected either by threading, welding or mechanical joints.

Testing of Pipes:

Pipes must be tested by air and not by water in the hydrostatic tests to avoid the problems resulted from the remaining moisture.

Air Tank:

Due to the interrupted operation of the compressor or the blower, the produced air is fluctuating in pressure and flow, and for the need of air with constant pressure and flow for filters washing and with quantities exceed sometimes flow rate of the compressor or the blower, air tank is installed to meet all technical requirements in the shortest time. In addition, the tank provides continuous operation of the compressor at load and stop at no load. It also removes the moisture from the air by condensation of water vapor in the air.

Components of air tank:

In addition to inlet and outlet pipes, air tank must contain pressure and air temperature indicators, valve for drainage of condensate vapor, pressure relief valve, safety valves adjusted on tank operation pressure and inspection holes.

Periodic time for filling and discharging air tank:

During discharge of the tank for use, the compressor supplies the compressed air to the tank; therefore operation of the tank is subject to the following equation:

$$T = \frac{V\ (P_1 - P_2)}{(c-s)\ Po}$$

Where:

T = Tank filling time (minute)

P_1 = Initial pressure of air received in the tank

P_2 = Final pressure of air received in the tank

P = Atmospheric pressure

C = Air rate required from the tank

S = Air rate received in the tank from the compressor.

V = Tank volume.

Tank Design Rules:

The tank is designed to withstand pressure 8.8 kg/cm^2 according American standard specifications ASME.

Table (2-1): Air Tank Specifications

Tank Diameter		Tank length or Height		Actual Compressor Capacity		Tank Volume	
Inch	**cm**	**F**	**m**	**F^3/min**	**m^3/min**	**F^3**	**m^3**
14	35	4	1.22	45	1.27	4.5	0.127
18	45	5	1.52	110	3.11	11	0.31
24	60	6	1.83	190	5.36	19	0.54
30	75	7	2.13	340	9.6	34	0.96
36	90	8	2.43	57	16.1	57	1.61
42	105	1	3.05	96	27.1	96	2.7
48	120	12	3.66	2115	59.7	115	3.25
54	135	14	4.27	312	88.1	223	6.3
60	150	16	4.88	44	124.3	314	8.88
66	165	18	5.49	6	169.5	428	12.1

2-8 Chemicals Building

Chemicals' building is designed to contain:

Handling equipments, dissolution tanks, suitable injection pumps, connection pipes to all chemicals used in purification works such as coagulants (alum or ferric chloride) and coagulants aid (polymers), pH corrector such as lime, and odor removal such as activated carbon according to type and condition of the raw water required to be purified and its need to these materials.

2-8-1 Dissolution tanks:

Three dissolution tanks are designed for each chemical material, volume of each one is enough for consumption of one full day or complete shift (8 hours at least), one is in operation, one for preparation and the third for emergency during maintenance. These tanks are made from reinforced concrete lined from inside by anti-chemicals ceramic tiles or made from fiber glass in case of small plants of compact units. Volume of the tank is determined according to the expected consumption per day or shift as follows:

$$= \frac{\text{Water flow rate / day (or shift) } m^3 \times \text{average of the used dose } (gm/m^3)}{\text{Solution concentration percentage} \times 10 \text{ (gm /liter)} \times 1000 \text{ (liter / } m^3)}$$

Each dissolution tank is provided with a mixer operated by electrical motor helps in dissolution of solid alum and prevents its settlement in case of leaving the tank for long period without direct use.

Usually ideal concentration of the chemical materials in the dissolution tanks does not exceed 10% for alum, 5% for ferric chloride and 1% for other materials.

2-8-2 Injection Pumps:

Pumps are selected for injection of dissolved chemical materials from coagulants and coagulants aid to the selected injection points of type with piston or diaphragm with single head of multiple heads according to number of injection points.

Special centrifugal pumps are also used for injection of lime solution and activated carbon due to their quick sedimentation in water. The dose is controlled by changing concentration degree of the solution or using control valves.

- Pump flow capacity must allow for pump and injection of maximum expected dose (of the used chemical material) and divided into number of pump heads in case of multiple injection points (clarifiers).
- The building is provided with three groups of pumps for each used chemical material, one in operation and the other for emergency in case of maintenance.
- Pump capacity is selected according to the following equation (liter/ minute)

$$= \frac{\text{Raw water flow rate } (m^3/h) \times \text{maximum expected dose } (gm/m^3)}{\text{Solution concentration percentage} \times 10 \text{ (gm /liter)} \times 60 \text{ (minutes / hour)}} \; 1.25 \times \text{pump safety factor}$$

Reciprocating Pumps (for chemicals)

Reciprocating Pumps are used to transfer the dissolved chemical solutions (alum, polymers and Hypochlorite). These pumps have constant speed and torque, and operate horizontally or vertically. They contain one piston or multiple piston or with diaphragm. They may contain simplex head or multiplex heads. The piston is either single effect or double effect.

Section of pumps design:

Pumps are selected according to the required flow and pressure as follows:

Required total flow:

It is the flow required to be pumped from the solution and necessary to achieve the dose specified for purification or disinfection and is calculated in liter/ minute as follows:

$$= \frac{\text{Raw water flow rate t injection point } (m^3/min) \times \text{maximum expected dose of chemical material } (gm/m^3)}{\text{Quantity if dissolved chemical material in liter } (gm\ /liter) \times \text{pump volume efficiency}} \text{ Liter / minute}$$

$$Q = D(1 - S)$$

Where:

D = Displaced capacity

S = Slip

D for pump with singe effect pistons:

$$D = 0.042\ A\ .\ m.n.L\ \ cm^3/min$$

Where:

A = Piston cross section area (cm^2)

m = Number of pistons

n = rpm

L = Piston stroke length (Cm)

For pump with double effect pistons

D = 0.042 (2A -a) .m.n.L

Where:

a = Piston arm cross section area (cm^2)

Slip

It is the loss percentage in suction capacity including loss of volumetric efficiency $\delta\, v_1$, loss of filler box B1 and suction valve loss v_1. This percentage is affected by viscosity, speed and pressure.

$$S = \delta\, v_1 + B1 + v_1$$
$$\delta\, v_1 = 1 - \delta\, v$$

Volumetric Efficiency $\delta\, v$

It is the ratio between discharged liquid volume to sucked liquid volume %

$$\delta\, v = \frac{\text{Discharged liquid volume}}{\text{Sucked liquid volume}}\ \%$$

Loss due to filler box B1

It is small and can be neglected because.

Loss due to suction valve η_{v1}

This loss ranges between 2% and 10% according to design and valve condition.

Head H

It is the pressure gained by the pump and is equal to (Discharge Head – Suction Head) and must not exceed injection point pressure (kg /cm^2 or k Pascal).

Speed:

Design speed of reciprocating pumps ranges between 5 to 12 rpm and depends on capacity, power and volume. To maintain life span of glands filler, the speed must be limited by the linear velocity of the piston which ranges from 0.7 to 0.75 m/s.

Pump speed depends also on pumps life and suction conditions to maintain the lubrication layer of the moving parts.

Brake H.P.:

$$B.H.P = \frac{W\,Q.H}{75\,\eta_m}$$

Where:

W = Specific weight of the solution (kg / liter)

Q = Flow rate (Liter / s)

H = Gained head (meter water)

η_m = Mechanical efficiency, ranges from 90-95%

Net Positive Suction Head (Required) NPSHr

Is the pressure required to ensure arrival of the solution required to be pushed from the tank to pump cylinder in the best operation. This net positive head required must be greater than net positive suction head available by 0.25 to 0.35 kg/cm^2.

Net Positive Suction Head Available NPSHav

Net positive suction head available consists of:-

Static head + Atmospheric pressure – (Head loss + Friction loss + liquid vapor loss + speed head + Acceleration head at suction line axis).

Acceleration head is the main factor in the above equation.

Acceleration Head (Ha):

It is known that flow in the suction line is fluctuating with increasing or decreasing acceleration continuously.

$$Ha = 0.3 \frac{L \cdot v \cdot n \cdot c}{g \cdot k} \quad m$$

Where:

L = Suction line length (m)

v = Average velocity in the suction line = flow / cross section area (m/s).

3- Design of Electrical Works

3- Design of Electrical Works

3-1 Electrical motors used in boosters

One of the following two types of the electrical motors is used in water purification plants:

A- Squirrel cage induction motors with powers up to 200 KW, and this value can be exceeded when using smart motor control systems.

B- Induction motors with slip rings with powers exceed 200 KW

The following conditions and specifications must be taken into consideration for the used electrical motors:

A- Motor windings must be with insulation degree (Class F) and the temperature rise for these windings must not exceed the allowed temperature for (Class B). Also can use motors with windings of insulation degree (Class H) and temperature rise must not exceed the allowed temperature for (Class F).

B- Motors Enclosure Protection

- For motors installed in motors house over floor level in the station, the used motors must be of closed type T.E.F.C. with enclosure protection IP44 or IP54

- For the motors installed directly over the pimp (Close coupled) and installed in pumps house under floor level, the used motors must be of (Flood proof) type with enclosure protection IP56.
- For motors installed outdoor and subjected to weather conditions, the used motors must be of (weather proof) type with enclosure protection IP55.
- For motors operating under water level, the used motors must be of (submersible) type with enclosure protection IP68. In this case, must specify the level at which the motor works under water level.

C- Motors must be provided with anti condensation heaters inside the windings to prevent condensation of water vapor in winter. These heaters work with the operating voltage 220 v.

D- When using vertically installed motors, they must be provided with thrust type ball bearings.

E- All used ball bearings must have lifespan 100,000 operating hours.

F- When using electrical motors with slip rings, they must be provided with brush lifting device with short circuit rings.

G- When using squirrel cage induction motors, commutating segments of the rotor which forming the cage must be from high quality copper.

H- Motor power required to drive the pump at the operating point is calculated from the following formula:

$$P = \frac{w\,Q\,H}{\eta_p \times 102}$$

Where:

W = Liquid specific density

P = Absorbed power on pump drive shaft (KW)

Q = Pump flow rate (liter/sec)

H = Pump total manometric head (m)

$_p\eta$ = Pump total efficiency at the operating point.

To calculate the rated power of the motor, must take into consideration the service factor of value 15-30% of the maximum power over operating time of the pump.

3-2 Switchgear

It includes closing and opening devices (switches) and their accessories, control devices, measuring devices, protection devices and adjustment as well as assembly of these devices and equipments, connections, supplies and the buildings containing them.

The following is identification of these equipments:

A- Metal enclosed switchgears

Switchgears assembled inside external metal enclosure connected with the earth. Complete with connections except the external connections.

B- Metal clad switchgears

Switchgears assembled inside separate cubicles contained in metal clad connected with the earth. Must take into consideration existence of separate cubicles for the following components in the switchgear:

- Main switch.
- The components connected at one side of the main switch as supply circuit.
- The components connected at the other side out from the main switch.

C- Circuit Breakers

They are mechanical control devices able to connect, hold and break the electrical current passing through under normal conditions of the electrical circuit. They are able also to connect, hold and break the electrical current for a limited period under abnormal conditions of the electrical circuit (short circuit).

D- Indoor Circuit Breakers

They are the circuits breakers designed to be installed inside the buildings or enclosed place, where they are protected against winds, rains, dusts, vapor condensation and other weather conditions.

E- Outdoor Circuit Breakers

They are the circuits breakers designed to be installed in the open atmospheres and are able to withstand different weather conditions.

F- Switches

They are mechanical control devices able to connect, hold and disconnect the electrical current under normal conditions of the electrical circuit. They are also able to withstand short circuit currents for limited period.

G- Disconnectors or Isolators

They are mechanical control devices give in open position separate distance prevents passing the electrical current at the rated voltage. The disconnetor is able to open and close the electrical circuit at no load or when the passing current in neglected (less than 0.5 ampere) where the voltage difference across the two terminals of each pole neglected.

H- Circuit Breaking

Circuit breakers (CBs) are defined according to their design and method of operation to break short circuit currents in the electrical circuit. CBs are classified usually according to the medium used in distinguishing the spark generated at disconnection. The electrical arc (spark) generated at disconnection and method of extinguishing is the main element in the function of the CBs, where it allows the current to continue passing in the electrical circuit after disconnection of the contacts until the current reaches to zero.

The ideal CB is the one that works as conductor until reaching the current to zero, at this point it is converted into absolute isolator. Practically, it is difficult to reach to a CB that can meet this condition, but must take into consideration to reach as near as possible to this condition with the necessity to provide the required conditions to remove the arising ionization in the contacting cavity and to use a medium withstands transient recovery voltage.

3-2-1 High Voltage Switchgear

High voltage switchgear must contain a set of cubicles allow to contain the circuit breakers and voltage transformers (at the connection side) in addition to be provided with the necessary installations to hold the measuring devices and relays and to be prepared to connect terminals of the supply cables and output cables.

The switchgears must be of metal enclosed or metal clad. The difference between the two types is that the current transformers and cable terminals are installed in one cubicle in metal enclosed type. For all types of circuit breakers, must provide possibility to remove the circuit breaker from the bus bars with one of the following methods:

- Vertical pull
- Horizontal pull
- Using disconnector or witch between the circuit breaker and the bus bars.

- In Bulk oil CBs, vertical pull is used.
- In Magnetic air CBs and Min. or Low Oil CBs, vertical pull is used.
- In case of Gas CBs, vertical pull or horizontal pull can be used.
- When using Vacuum CBs, usually fixed type CBs is used with the existence of disconnector between the circuit breaker and the bus bars to get benefit from the feature of this type of less maintenance.
- Must take into consideration to provide safe installations to access to the main bus bars of the distribution boards to perform the required measurements and tests. In case of CBs of pull type, the access to the bus bars will be through the holes used in engaging the circuit breaker.

3-2-1-1 Interlocking & Padlocking

To ensue safe operation of the electrical switchgears, especially when it is required to access to the bus bars for troubleshooting or to connect a phase of the circuit or to test the cables, the board must be supplied with mechanical interlocking or padlocking to control connection of the main supply to these switchgears.

The first requirement for the interlocking in all types of switchgears provided with CBs of pull type, is to ensure that the CBs can not be pulled or engaged while they are connected (closed) with the current. The switchgears must be provided with metal shutters to cover connection holes to bus bars automatically when pulling the CBs from their operation cubicle. Similarly, preparation must be performed in order to close these shutters in disconnection position to ensure safety of all the equipments contained in the cubicle.

3-2-1-2 Types of Circuit Breakers

The common types that currently used are:

A- Oil Circuit Breaker

Is divided into:

- Bulk oil CB
- Minimum Oil CB

Hydrocarbon oil is used in this type of CB of low viscosity and good insulation properties.

Disadvantage of this type is the rise of contacts temperature which leads to oil evaporation and dissolution to its components of hydrogen and carbon, where the hydrogen is thermally ionized to produce electrons and positive ions have the ability to carry the electric current within the distance between the contacts causing electric arc. To control gas flow in the spark area, the contacts must be closed inside the control range of the arc by using arc control device to increase efficiency of operation of the circuit breaker.

B- Magnetic air circuit breaker

Its theory of operation depends on creation of very high voltage for the arc can not be kept by the used operating voltage, hence the arc can not continue. It can reach to this by enforcing the arc to extend to reach near to solid materials that extract the heat from the arc or by breaking the arc into series of arcs. The two methods can be used together in some designs, where the magnetic circuits create a field inside the arc range to guide the arc within this range. In case of low electric currents (about 100 A), air blower must be added and connected with vents below the contacts to guide the arc.

C- Vacuum circuit breaker

The contacts in this type are inside sealed air vacuumed container with insulating walls. One of the contacts is fixed with the terminal of the circuit breaker and the other contact is free in motion in axial direction through metal gaskets connected between the moving contact and the other connecting end. Performance of the vacuum circuit breaker depends on the following three factors:-

- Existence of enough vacuum inside the device
- Select suitable material for the contacts.
- Provision of magnetic control in the arc.

Contact gap is about 10 mm for voltages up to 11 KV; therefore, the power necessary for operation is less than the other types of CBs. This type achieves the highest efficiency of operation as a current disconnecting device, where the insulation strength of contact gap is recovered within (1) microsecond within the rated break current. Because of the high strength of these CBs, they do not require any maintenance over their lifespan and there is no possibility of fire due to absence of any flammable materials.

D- Sulphur Hexa Fluoride CB (SF6)

It contains inert non-flammable, colorless, odorless Sulphur Hexa Fluoride gas. The gas is used at pressure of about 3 bar to reach to the same insulation strength of mineral oil. This gas is characterized by absorption of the free electrons generated in the path of the electric arc forming negative ions which speeds up recovery of the insulation strength after occurrence of the arc. The activated ammonia is used to absorb less degree fluoride gases (SF2 & SF4) which may be produced due to dissolution of the original gas SF6. For this reason, this type of CB can withstand a significant number of breaks in cases of short circuit without the need to change its active parts.

Table (2-2) shows comparison between characteristics of types of the CBs

3-2-2 (H.V) Switchboard Construction

Each board consists of number of cells; each cell consists of metal structure lined with cold rolled steel plates of thickness not less than 2 mm. The board is provided with front and rear doors for easy maintenance. It is also provided with the necessary precautions for safe operation and maintenance. Equipments of each cell are installed separated and insulted from the adjacent cell. The life parts are kept away of being touched after pulling the switch from inside the cell.

Distribution bars are made from good conducting copper completely insulated by suitable material. Contact point must be of self aligning type loaded with strong spring coated with thick layer of silver. The boards are provided with mechanical and electrical interlocking for safety of operation.

3-2-3 Low Voltage Switchgear

Low voltage switchgear are subject to IEC. Low voltage circuit breakers are designed, manufactured and tested according to IEC 157-1/1973 and amendments thereof. The following specifications must be taken into consideration:

(A) Short circuit categories.

Table (2-2): Comparison between types of H.V Circuit Breakers

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker III	SF6 CB IV
1	Connection and disconnection of inductive current	At low currents, it has the feature of quiet extinguishing of spark for many half cycles which produces current chopping then voltage-surge.	As the oil is a good insulator, extinguishing of the spark (electric arc) is more effective than the air CB. This give shorter time of the spark and higher degree of current chopping and considerable increase in voltage, but with insufficient value that may damage the insulation.	The breaker will disconnect regardless the value of the passing current. Stability of the electric arc (spark) at small currents depends on contacts material used in the CB, where spark plasma (medium) consists of vapor of the metal from which the contacts are made.	Path of the current chopping depends on method of extinguishing the spark, generally, of the same value as in oil CB and vacuum CB.
2	Connection and disconnection of capacitive current	Tends to recover the spark after distinguishing. It has very limited value in performing this function.	Has insulation strength for each pole enough to ensure break of the capacitive current without return of the spark	Very quick recovery of the insulation strength for the vacuum gap. This provides break without return of the spark to the capacitive currents until the full load of the rated current for the breaker.	Due to the negative electricity properties, the conduction gap is quickly re-ionized which provides break without return of the spark.
3	Mechanical aspect	The standard specifications require achievement of 1000 connection and disconnection processes at no load without affecting the breaker in addition to neglected wear degree. Regular lubrication during this period must be taken into consideration in the design.		Short stroke for connection and disconnection and low power requirements, help the designer to develop strong mechanical structure for long lifespan without performing maintenance for these CBs. Usually, 10,000 connection and disconnection processes at least are achieved without maintenance.	Power requirements are located between those of oil CBs and vacuum CBs. Most of the required power is used to extinguish the spark. This power is increased as the rated current of the CB increases. Theses CBs require maintenance at periods usually reach to 1000 connection and disconnection processes.

Table (2-2): Comparison between types of H.V Circuit Breakers

<table>
<tr><th>No</th><th>Characteristics</th><th>Air circuit breaker
I</th><th>Oil circuit breaker
II</th><th>Vacuum circuit breaker
III</th><th>SF6 CB
IV</th></tr>
<tr><td></td><td></td><td colspan="2">If there is no great risk of fire, the great switchgears are divided by fire walls built across the building to reduce risks of damage of the switchgears in case of fire breakout. Length of the building depends on the width of each unit (cell) in the switchgear, in addition to the space necessary for the firewalls (if any) and the paths of the bus bars. Cells width must be lesser in case of the submersible CBs in oil than in the air CBs or low oil CBs.</td><td>As the width of cells is small, the length of the building is shorter and lighter in construction than in the conventional switchgears, which significantly decreases cost of the building.
In case of pull type CBs, the building is wider, but saving in use of fire walls and fire fighting equipments is still exit and hence the building is more economic.</td><td></td></tr>
</table>

Table (2-2): Comparison between types of H.V Circuit Breakers (Cont.)

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker III	SF6 CB IV
4	Confusion in the CB during the fault				
	(A) Value of the produced pressure	Quick existence of the electric arc in the arc-chute produces high pressure and impact waves that must be taken into consideration in the mechanical construction of the CB which increases the cost.	Dissolution of the oil to hydrogen and hydrocarbons by electric arc current produces very high pressure inside the spark control device. This affects the ability of extinguishing. Part of this pressure is transferred to the metal tank, but the existence of suitable air pad near the tank cover helps to keep the pressure inside the tank. Using of cylindrical tank makes this increase in pressure simple matter.	Increase in metal vapor intensity produced during occurrence of the electric arc in contact chute is synchronized with the current and there is no general increase in pressure inside the CB.	Internal pressure formed during fault period reaches two or three times of the static pressure. This must be taken into consideration in design of insulation chamber.
	(B) Emission of exhaust gases	The great amount of ionized air flowed from the arc chute creates the need to cool down the insulation and the existence of trenches to allow safe flow of this air.	Medium amounts of exhaust gases are flowed, which can pass through blocking chamber at the upper surface of the CB. This cools and separates the gases from the oil.	The CB is completely enclosed and all the metal vapors produced during the electric arc (spark) are immediately condensed and there are no emissions of any type for these vapors.	The CB is completely closed and there is no emission of gas and may some of it dissolved to its components of sulphar, free sulphar, where they are absorbed by special filters inside the CB, gas leakage can be controlled less than %1 annually.

Table (2-2): Comparison between types of H.V Circuit Breakers (Cont.)

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker III	SF6 CB IV
	(C) Effect on CBs bases	Very small	Small	Neglected	Little
	(D) Production of Noise	Small	Medium	Neglected	Little
5	Possibility of Fire	As there is no oil used and non-flammable gases, the hot burning gases produced during the fault contain low degree of fire outbreak.	Using the oil as break medium and hence emission of inflammable gases (hydrogen, acetylene, methane, etc) during this process, this represents risk of fire outbreak. Good design of the CBs rarely give increase in the gases that may cause fire except in the occurrence of sever errors. It must exist controls and precautions against fire in case of using these CBs in environments that the fire has adverse effect.	Risk of fire outbreak is neglected, as there are no inflammable materials or gases from any sources.	As in Vacuum circuit breaker III.
6	Maintenance Requirements (A) Routine Maintenance	Routine maintenance in the traditional CBs includes cleaning and lubrication of the mechanical parts, inspection of the contacts, spark control device, insulation medium and replacement, if necessary.		Need non-periodic inspection to know the condition of the insulation material, electrical insulators and maybe CB contacts to check existence of wear.	These CBs are designed for long lifespan with non-periodic maintenance.

Table (2-2): **Comparison between types of H.V Circuit Breakers** (Cont.)

No	**Characteristics**	**Air circuit breaker I**	**Oil circuit breaker II**	**Vacuum circuit breaker III**	**SF6 CB IV**
		Rate of this procedure depends on the required performance, and it ranges from monthly service, in case of heavy duty (many connection and disconnection processes per day), to periods between 3-5 years for public supply. The oil must be replaced periodically in case of repeated use of oil CBs more than any other consideration, and the low oil types need more care especially the totally submersed types.		The number of operation processes can be recorded to determined periods of performing inspection. In case of public supply boards, replacement may be done during the lifespan of the CB, while in case of heavy duty (Daily repeated loading), replacement may be done every a number of years.	Mostly, maintenance cycle every 10 years is suitable for this type, but a visual inspection must be performed regularly. Safety measures must be taken in case of existence of existence of opening to provide the gas. Special equipments are used to do.
	(B) Post- Fault Maintenance	Usually, it is proposed to perform post-fault maintenance as soon as possible to recover the CB to its normal and safe condition.		It is not necessary to perform this maintenance, but it is preferred to inspect the CBs after operation during the normal operating period.	The same as vacuum CBs.
7	Maintenance suitable for risk environment conditions and repeated operation.	Required care and performing repeated maintenance for the CB insulator faces.	It is suitable, but always requires provision and adjustment of oil level and change of the contacts, especially in heavy duty cases. Maintenance will be repeated more in case of low oil CBs.	Features of the CB is more clear in these conditions, hence annual operation costs are less compared to the other types.	Does not need repeated maintenance, but care must be given to the mechanical parts in case of repeated operation, especially if the close power is high.

Table (2-2): **Comparison between types of H.V Circuit Breakers** (Cont.)

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker III	SF6 CB IV
8	Operation Facilities (A) Integral Fault Making Earthing Facilities	Rarely have this feature, but if necessary, separate earthing units are used.	Easy provision of integral fault making earthing for vertical pull CBs.	Are provided with this feature in case of fixed CBs, while for pull type CBs, the same as in I and II according to method of disconnection (vertical or horizontal)	As in I and II according to the type of pull, vertical or horizontal).
	(B) Injection- Test Facility	Requires removing the CB from the board then inserting the test stick into disconnection socket.		In case of fixed CBs, it will be provided with test openings that enable to insert test stick while the circuit is earthed. In case of pull type CBs, as in I and II.	As in I and II
9	Design of Switchboards Building	Width of the building depends on the depth of the switchgears with the existence of inlet path for cable terminals at rear of the board and wide passage at front of the board to give space to pull the CB and perform maintenance. According to the dynamic loads on the floor during operation, strong and expensive bases are constructed. Fire fighting equipments, such as carbon dioxide extinguishers are used, or using other systems as sprinklers or gas incase of risk of fire breakout. If there is no great risk of fire		In case of fixed CBs, there is no need for space in the design for pull or maintenance, so the width of the building is lesser than in case of pull type CBs. Loading on the floor is light and there is no need for fire walls or fire fighting equipments.	Operation group using gas CBs shall be of pull type CBs and the building requires a space for this purpose, but risk of fire breakout is neglected and there is no need for fire walls or fire fighting equipments, hence the building is more compact and simple.

(B) Short Circuit Tests Method

(C) Temperature-rise limitations / Thermal ratings

- Table (2-3) shows two short-circuit categories, and it is clear from the table that short-circuit category P1 is capable to select the two types O-CO at maximum short-circuit rating, while short-circuit category P2 is capable to select O-CO-CO. The main difference between the two categories P1 and P2 is that P1 is capable to operate after performing the specific test with reduced service, while P2 is capable to operate with normal service. Therefore, this difference must be taken into consideration and clearly specify the required category when developing the specifications of these CBs.

- When performing short-circuit tests for the CBs, must take into consideration to perform these tests in the same operating conditions as those applied during the service.

- Table (2-4) shows temperature rise limit according to IEC standard and must take into consideration always that temperature rise in the contacts does not lead to damage of insulation or to the parts adjacent to the contacts.

Table (2-3): Short Circuit Categories

Short-circuit categories

IEC 157-1 has two categories of short-circuit performance outlined in table 12.2.

Short-circuit performance category	Rated operating sequence for short-circuit making and breaking capacity tests	Condition after short-circuit tests
P1	O - t- CO	Required to be capable of performing reduced service
P2	O - t - CO - t - CO	Required to be capable of performing normal service

O represents a breaking operation.

CO represents a making operation followed, after the appropriate opening time (or immediately, that is without any intentional time delay, in the case of a circuit-breaker not fitted with integral overcurrent releases) by a breaking operation.

t represents a specified time interval.

It can be seen that the P1 cb has to be capable of a type test duty O - CO at its ultimate short-circuit rating, while the P2 cb has to be capable of a type test duty O - CO - CO.

However, the most significant difference between categories P1 and P2 is that a P1 cb need only be capable of reduced service condition after the test, whereas the P2 cb has to be capable of continued normal service.

Table (2-4): Temperature Rise Limit according to IEC Standard

Type of material, description of part	Temperature-rise limit (measured by thermocouple)
Contact parts in air (main, control and auxiliary contacts):	
copper	45°C
silver or silver-faced*	(1)
all other metals or sintered metals	(2)
Contact parts in oil	65°C
Bare conductors including non-insulated coils	(1)
Metallic parts acting as springs	(3)
Metallic parts in contacts with insulating materials	(4)
Parts of metal or of insulating material in contact with oil	65°C
Terminals for external insulated connections	70°C(5)
Manual operating means:	
parts of metal	15°C
parts of insulating material	25°C
Oil in oil-immersed apparatus (measured at the upper part of the oil)	60°C(6)

*The expression 'silver-faced' includes solid silver inserts as well as electrolytically deposited silver, provided that a continuous layer of silver remains on the contacts after the endurance tests and the short-circuit tests. Contacts faced with other materials, the contact resistance of which is not significantly altered by oxidation, are treated as silver-faced contacts.

(1) Limited solely by the necessity of not causing any damage to adjacent parts.
(2) To be specified according to the properties of the metals used and limited by the necessity of not causing any damage to adjacent parts.
(3) The resulting temperature shall not reach a value such that the elasticity of the material is impaired.
(4) Limited solely by the necessity of not causing any damage to insulating materials.
(5) The temperature-rise limit of 70°C is a value based on the conventional test of Clause 8.2.2.2. A cb used or tested under installation conditions may have connections the type, nature and disposition of which will not be the same as those adopted for the test; a different temperature rise of terminals may result and this will have to be agreed.
(6) May be measured by thermometer.

3-2-4 Thermal rating and Enclosed rating

Is the rating of the CB in ampere listed in the data plate of the CB, such as thermal rating for the un-enclosed devices and provided with overload breaker, if necessary, which is the maximum current than can pass in the CB for 8 hours when tested in the open air provided that the temperature rise does not exceed the limits specified in table (2-4). So, must take into consideration that this rating does not express the rating of the CB at installation inside the switchgears. The enclosed rating of the CB is defined as the thermal rating inside the closed CBs, which is the maximum current, can pass through the CB for 8 operating hours when installed inside enclosure with certain specifications without temperature rise of its different parts over the limits specified in Table (2-4). Hence, normal full load current of the CB must not exceed the rating inside the enclosure, which is lesser than the thermal rating of the CB. To obtain acceptable operation of the CBs, rating in ampere of the CB must be taken into consideration inside the switchgear, where its rating is affected by the degree of ventilation and size of connections of this CB. Size of the cable used in connection depends on the number of CBs installed in the same raw. To reach to good and acceptable performance for switchgears, must ensure operating of the CBs in all surrounding operation conditions and performing the tests for them inside the same board they installed.

Therefore, the manufacturer of the switchgears, whether if it is the manufacturer of the CBs or that assembling the CBs inside switchgears of its design, must be given test certificate directly related the conditions surrounding the CBs when actually operated and ensure acceptable operation in actual operation conditions.

3-2-5 Construction of 380 v distribution switchgears

Walls and ceiling of the distribution switchgears are from steel of thickness not less than 1.5 mm and are painted internally and externally by two layers of approved paints. Its structure consists of strong steel corners welded or tied with the walls provided that the each cell is separated, and fixed with the other adjacent cells by suitable methods and contains all the necessary devices to allow easy operation and maintenance of all board devices by the operator. Each cell must be provided with rear steel door with key. The switchgear must be provided with the required switches and devices and all of their connections, insulators, CBs, fuses and terminal blocks for the inlet cell and what are necessary for its operation. All devices are fixed inside each cell at the rear of the front face of the board provided that only appear the meters of submersible type, switch handles and the indicator lamps. Distribution bars and their connections must be from good copper conductors installed on china insulators or bakelite suitable for the operating voltage and does not allow for temperature rise in distribution bars more than 40°C. It is not allowed welding in distribution bars and the cross section of the copper must be according to the design provided that the current density not exceed 2 A/ 1 mm^2 of the cross section. The cross section must not less than 250 mm^2. Connections system must be easy to be followed and each phase must have separate color, red, blue and yellow, respectively, and the neutral is black color. The main copper cross section must be the same in all board parts.

3-2-6 Earthing

All un-life parts of the switchgear, one terminal of current and voltage secondary windings and meters must be connected to the earth. These connections must be connected safely.

Earthing wire shall be made from ordinary copper or (braid) with suitable cross section connected to all doors of the switchgear and the devices subject to touch and one side of the secondary winding of voltage and current transformers, control and measuring devices, etc.

3-2-7 Earthing Well

Earth wires are connected to special well constructed adjacent to the plant according to the following specifications:-

Earthing well consists of galvanized iron pipe of diameter not less than 2 inches buried inside the ground with length 4 meter or until it reaches below groundwater level with a distance not less than 80 cm. The length flooded by the groundwater must be perforated with not less than five holes on the circumference for each 2 cm of the axial length of the pipe.

The pipe is surrounded from outside by a mixture of sodium chloride and fine crashed coal in low humidity dry soil. Ordinary copper bar is extended inside the earth pipe and tied at the top of the pipe where a galvanized iron bush is installed. Welding is not allowed.

The upper part of the pipe of length 20 cm is protracted inside a cast iron box with hinged cover. The dimensions of the box is not less than 35cm × 22cm. This box is installed with the cover at the level of the ground surface.

Earth wire of the plant is connected to the earthing pipe by electric welding or with tying screws. Tin welding is not allowed.

3-3 Electrical Transformers

Distribution Transformers

Distribution transformers are used for public and industrial uses. They are usually of power 1600 KVA or less. Also, for economic reasons, transformers of power up to 2500 KVA may be used.

Definition of Transformers

Transformers are defined as the static part of the devices, which through electromagnetic induction, transform the AC voltage and current between two or more windings at the same frequency, usually at different values of voltage and current.

3-3-1 Types of the used transformers

There are two types of distribution transformers:

- **First Type: Liquid Filled Transformer**. In which the core the windings are flooded inside enclosure filled with liquid which provides cooling and insulation at the same time.
- **Second Type: Dry Type Transformer**. In which the core and the windings are cooled directly with air (Dray Transformers).

The first type is divided into units use inflammable mineral oils and other use different types of fire proof liquids, such as silicon liquids or hydrocarbons compounds.

The second type is divided into two units. In the first unit the insulated windings are in direct contact with the cooling air, and in the second the windings are enclosed completely inside capsule of moisture proof materials made from cast-resin.

3-3-2 Common Powers of Transformers

Table (2-5) shows the power ratings commonly used in the commercial electrical transformers**.**

3-3-3 Tappings

High voltage windings of the transformers contain tappings to change windings ratio between the low voltage and high voltage windings to equate the change of the primary supply voltage to keep the secondary voltage for the consumer within the rating limits. The tappings are selected through external circuit. The transformer must be disconnected from the supply before change the tappings.

3-3-4 Transformer Windings

The transformer consists of three branches core made from electrically insulated steel laminations. Each branch holds two axially winded windings. The secondary winding (low voltage) is the inner part near from the iron core, the primary winding (high voltage) is the outer part. This combination is put inside steel enclosure.

In case of transformers of flood type, this enclosure consists of sealed tank filled with liquid. In case of dry transformers the enclosure consists of ventilated cover to contain the life parts.

Table (2-5): Power ratings commonly used in the distribution transformers

KVA	KVA	KVA
5.0	31.5	200
6.8	40	250
8	50	315
10	63	400
12.5	80	500
16	100	630
20	125	800
25	160	1000 etc.

The windings are mostly manufactured from copper except in special cases aluminum thin strips can be used.

3-3-5 Transforms Performance

When selecting the transformer, the preliminary cost must not be the only consideration. In most cases, small part is cost from the total cost.

The factors that control the selection of a certain transformer, must take into consideration the load factor, losses cost, efficiency, maintenance cost, fire fighting quality and the required building cost, the available area for construction and air temperature in addition to the preliminary cost.

3-3-6 Losses in the Transformers

- No-load and load losses in the transformer represent loss in the efficiency and is the reason for the great part of transformer operating cost. These losses are transferred to heat and usually removed through radiation in the environment surrounding the transformer.
- Different suppliers of the flood transformers are compared in terms of electricity consumption and the resulted no-load losses in case of continuous activation of theses transformers.
- Load losses cost depends on the load factor (L.F.), which does not differ significantly between products of the same power in case of oil transformers. In case of transformers immersed in fire proof materials, these losses are significantly different.

- Losses in the dry transformers are lesser than in case of the immersed transformers.
- Table (2-6) shows comparison between the different types of transformers of power 1000 KVA. The same comparison must be performed between types of transformers for all other powers before taking any decision for preference of a type from other one as a factor of reference.

3-3-7 Temperature Rise

- In temperate weathers, the difference in the temperature rise limits between the immersed transformers and dry transformers is neglected in the combinations.
- Rise in the ambient temperature of the transformers limits their power ratings, where they are less than the value indicated on the data plate of the transformers. The radiated heat due to losses affects also the electrical devices of these transformers.
- Table (2-7) and Table (2-8) show temperature rise limits for the two types of transformers.
- For the transformers installed inside the buildings, when the ambient temperature is very high, it is preferred to use dry transformers, reduce their powers to a value equivalent to this temperature and perform the periodic maintenance due to the sensitivity of this type and prevent pest from reaching to them.
- For the transformers installed in high temperature areas or inside very confined places, it is better to use transformers manufactured specially for high temperatures and immersed in silicone liquids.

Table (2-6): Comparison between electric losses in some types of transformers

(1000 KVA)

	Losses in kilowatts at operating temperature								
	No load	1/4 Load		1/2 Load		3/4 Load		Full load	
Oil		No load	2.8	No load	2.8	No load	2.8	No load	2.8
Askarel	2.8	Load	0.6	Load	2.3	Load	5.2	Load	9.1
Silicone		Total	3.4	Total	5.1	Total	8.0	Total	11.9
Dry-type, 150°C	3.2	No load	3.2	No load	3.2	No load	3.2	No load	3.2
		Load	0.8	Load	3.3	Load	7.4	Load	13.2
		Total	4.0	Total	6.5	Total	10.6	Total	16.4
Epoxy dry-type	3.2	No load	3.2	No load	3.2	No load	3.2	No load	3.2
		Load	0.7	Load	3.0	Load	6.7	Load	11.8
		Total	3.9	Total	6.2	Total	9.9	Total	15.0

Table (2-7): Temperature-rise in dry transformers

1	2	3	4
Part	Cooling method	Temperature class of insulation*	Maximum temperature rise (°C)
Windings (temperature rise measured by the resistance method)	Air, natural or forced	A E B F H	60 75 80 100 125 150†
Cores and other parts (a) Adjacent to windings (b) Not adjacent to windings	All		(a) Same values as for windings (b) The temperature shall, in no case, reach a value that will damage the core itself, other parts or adjacent materials

Note. Insulating materials may be used separately or in combination provided that in any application each material will not be subjected to a temperature in excess of that for which it is suitable, if operated under rated conditions.

*In accordance with IEC Publication 85, Recommendations for the Classification of Materials for the Insulation of Electrical Machinery and Apparatus in Relation to their Thermal Stability in Service.

†For certain insulating materials, temperature rises in excess of 150°C may be adopted by agreement between the manufacturer and the purchaser.

Table (2-8): Temperature-rise limits in oil transformers

1	2
Part	Maximum temperature rise (°C)
Windings: class of insulation A (temperature rise measured by the resistance method)	65, when the oil circulation is natural or forced non-directed 70, when the oil circulation is forced and directed
Top oil (temperature rise measured by thermometer)	60, when the transformer is equipped with a conservator or sealed 55, when the transformer is neither equipped with a conservator nor sealed
Cores, metallic parts and adjacent materials	The temperature shall, in no case, reach a value that will damage the core itself, other parts or adjacent materials

Note The temperature rise limits of the windings (measured by the resistance method) are chosen to give the same hot-spot temperature rise with different types of oil circulation. The hot-spot temperature rise cannot normally be measured directly. Transformers with forced-directed oil flow have a difference between the hot-spot and the average temperature rise in the windings which is smaller than that in transformers with natural or forced but not directed oil flow. For this reason, the windings of transformers with forced-directed oil flow can have temperature rise limits (measured by the resistance method) which are 5°C higher than in other transformers.

3-3-8 Loading Guide of Transformers

- The ambient temperature and service conditions can be determined for the oil transformers without occurrence of damage for windings insulation due thermal effects in case of exceeding the allowed limits. The same units can be applied in case of use of other types of cooling liquids.
- Purpose of the loading guide is to give the allowed limit under certain conditions of cooling medium temperatures and the primary loading percentage of the rating power (of normal operation position) in order that the designer can select the rating power for any new constructions.
- Determine normal cooling medium temperature (e.g. 2°C) and the deviations from this value in order to achieve balance between elongating of the lifespan in case of operating under lower temperature and shortening this lifespan in case of operating at higher temperature.
- In the practical applications the transformers are not operated continuously under full load. The guide gives suggestions for daily loading cycle taking into consideration change in the ambient temperature during seasons of the year.
- Table (2-9) shows loading guide for the oil transformers at 20°C of cooling medium.
- By this table, overload of a transformer with certain rating power can be determined during certain period of time or determine the required rating power for a transformer with daily loading cycle through drawing a curve for the relation between K1 and K2 at different values for the loading periods (t) (Fig 2-42).

Table (2-9): Loading Guide for Oil Transformers

K_1 = initial load power as a fraction of rated power

K_2 = permissible load power as a fraction of rated power greater than unity)

t = duration of K_2 in hours

θ_a = temperature of cooling medium (air or water).

Note $K_1 = S_1/S_r$ and $K_2 = S_2/S_r$ where S_1 is the initial load power, S_2 is the permissible load power and S_r is the rated power.

Values of K_2 for given values of K_1 and t

	K_1 = 0.25	K_1 = 0.50	K_1 = 0.70	K_1 = 0.80	K_1 = 0.90	K_1 = 1.00
t = 0.5	+	+	<u>1.93</u>	<u>1.83</u>	<u>1.69</u>	1.00
t = 1	<u>1.89</u>	<u>1.80</u>	<u>1.70</u>	<u>1.62</u>	1.50	1.00
t = 2	<u>1.59</u>	<u>1.53</u>	1.46	1.41	1.32	1.00
t = 4	1.34	1.31	1.27	1.24	1.18	1.00
t = 6	1.23	1.21	1.18	1.16	1.12	1.00
t = 8	1.16	1.15	1.13	1.12	1.09	1.00
t = 12	1.10	1.09	1.08	1.07	1.05	1.00
t = 24	1.00	1.00	1.00	1.00	1.00	1.00

ONAN and ONAF transformers: θ_a = 20°C.

Note In normal cyclic duty the value of K_2 should not be greater than 1.5. The values of K_2 greater than 1.5, underlined, apply to emergency duties.

The + sign indicates that K_2 is higher than 2.0.

3-3-9 Fire resistance

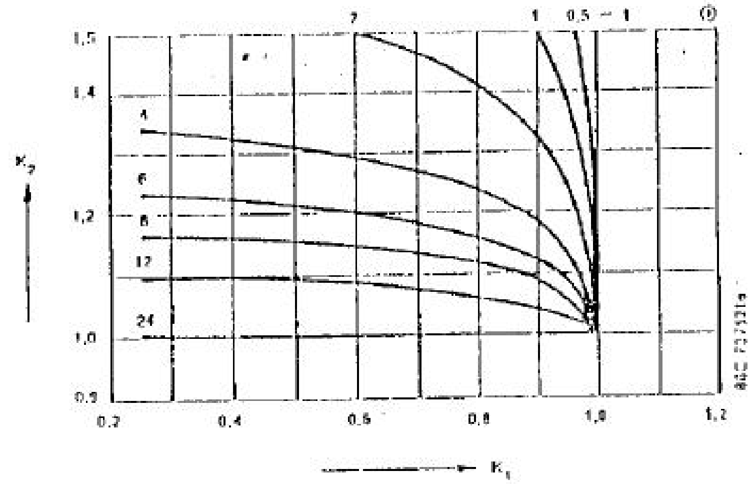
Dry and immersed transformers (except mineral oils) are considered fire proof, this does not mean these materials are non-inflammable although these materials have fire point (is the temperature at which occurs continuous burning of the material when subjects to flam at its surface). The most important factor that must be taken into consideration is material resistance to fire and to be the fire point of the material more high than the maximum temperature of the transformer at full load in worst weather conditions.

- Table (2-10) shows fire point for some fire proof materials (carbonaceous materials are excluded for their danger on the environment). From the table it is clear that there is no great difference between the materials except insulation Class H, which can be considered practically fire proof. Poisonous effect of the vapors emitted from burning of these materials and the resulted danger must be taken into consideration in addition of the other features for comparison purpose.

Removal Heat Rate (RHR) resulted from the burned material is considered an important factor, where depend on it size and nature of the transformer enclosure. This rate consists of two components, one is convective and the other is radiative. The first component is higher in value and is considered a measure of destruction to the ceilings of the transformers buildings, while the second component shows the destructive effect of the fire on the walls and the equipments surrounding the transformer.

- Table (2-11) shows values of these components for some fire proof materials.

Assuming the same service life as for continuous operation at rated power and at an ambient air temperature of 20° C, the transformers may be subjected to a load cycle as shown by the curves below.



The curves are in accordance with the IEC recommendation of 1972 which permits a hot-spot temperature in the windings of 140° C.

in which:

K_1 = initial load referred to rating

K_2 = max. permissible load referred to rating

t = duration of K_2 in h

Note:

In certain cases the permissible overload obtained from the above curves may be limited by the tap changer and bushings. Therefore, if it is intended to operate the transformer with a load cycle involving overloads, the height of the latter and the nature of the load cycle should be stated.

Fig (2-42): Relation between K1 and K2 at different values of loading period t

Table (2-10): Fire point for some fire proof materials

Material*	Fire point (°C)
Silicone liquid	360
Midel 7131	310
Cast resin	350
Class H	†

*For comparison purposes mineral oil is 170°C. Askarel is non-flammable.

†These designs are virtually fire proof.

Table (2-11): Removal Heat Rate (RHR) values for some fire proof materials

Material	RHR	
	convective (kW/m^2)	radiative (kW/m^2)
Silicone 561	53	25
High fire point hydrocarbon	546	361
Epoxy resin	-	-

3-3-10 Connections

- Secondary windings of the distribution transformers are connected at the low voltage side in star connection (**Y**) and the system is earthed at the neutral point to obtain single voltage.
- The primary windings are connected at the high voltage side in delta connection (**Δ**) to eliminate the triple harmonics.
- The commonly used connections, according to the shift between the same phase in the primary and secondary windings, are: Dy 11, Dy 5 or Dy 7. Dy11 or equivalent is the most commonly used in the world.
- Fig (2-43) shows these connections in addition to other connections.

  In this figure, HV vector diagram is taken as the original vector and the similar phase in the LV windings is related to it according to clock hour figure.
- Phase shift test for primary windings (High Voltage) and the secondary windings (Low Voltage) is neglected in case of use only one transformer for area network. If the network contains more than one transformer, all transformers must have the same phase relation, otherwise the transformers can not be operated in parallel or to covert the supply of the network from a transformer to another.

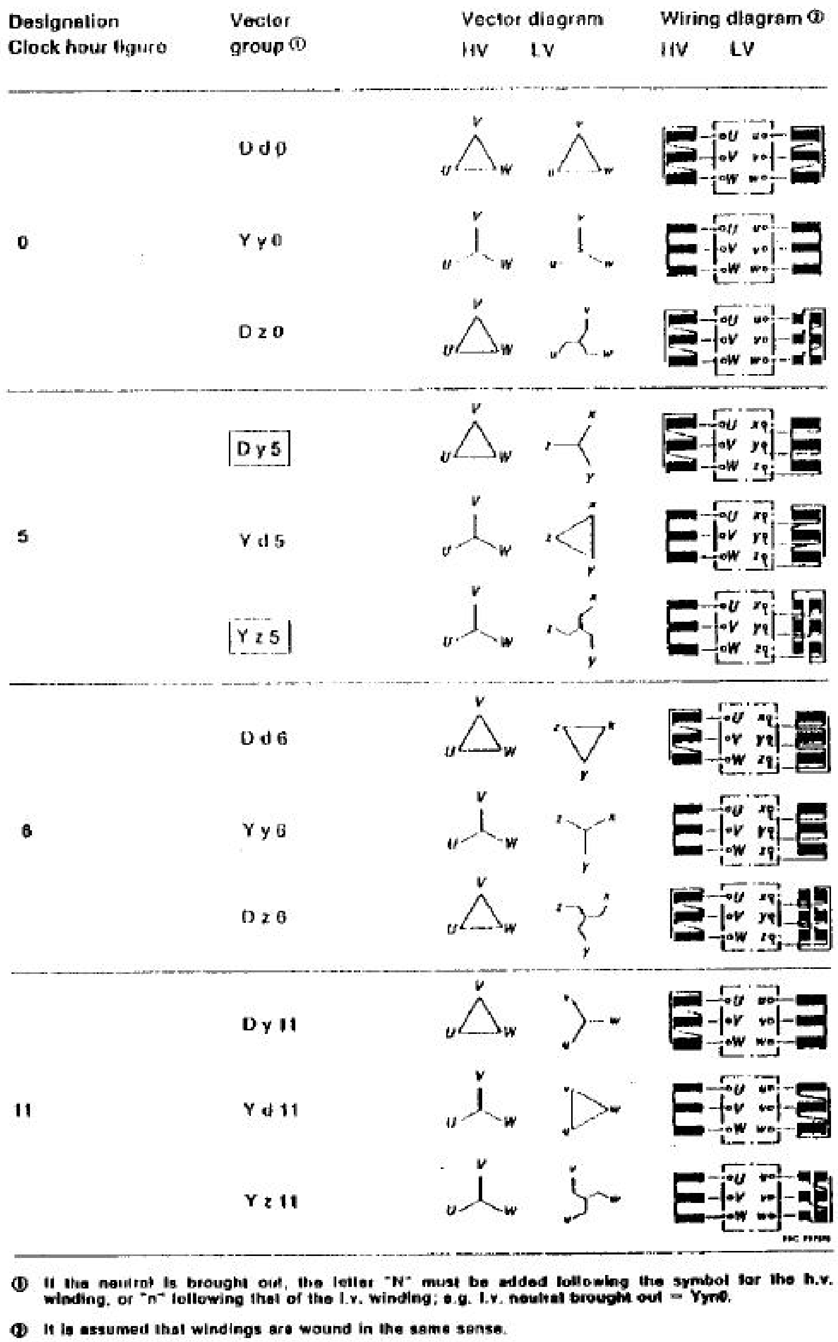


Fig (2-43): Commonly uses vector groups in distribution transformers

3-3-11 Terminals

- LV Terminals in the transformers are in the form of epoxy resin case contains set of pins connected to it cable terminals with screws.
- HV terminals are in the form of cables box filled with compound in case of paper insulated HV cables or upper cables box in case of XLPE or P.V.C cables provided with thermal shrinkable sleeves.

3-3-12 Transformers Cooling

Transformers are identified according to the used method of cooling. Table (2-12) shows the alphabetic letters used as symbols to indicate the cooling method.

- The simplest cooling methods are done by cooling the windings by natural air passing over the hot surfaces of the windings and transformer core, where heat is transferred to the air surrounding the transformer by convection of radiation. This method is described as Air Nature (A.N.).
- To overcome the obstacles that reduce heat transfer from the windings to air, forced-directed air is used over these windings to improve heat flow and increase cooling rates significantly. This method is known as Air Forced (A.F.).

Table (2-12): The alphabetic letters used as symbols to indicate the cooling method in distribution transformers

Kind of cooling medium	Symbol
Mineral oil or equivalent flammable synthetic insulating liquid	O
Non-flammable synthetic insulating liquid	L
Gas	G
Water	W
Air	A
Kind of circulation	
Natural	N
Forced (oil not directed)	F
Forced-directed oil	D

- These two methods can be combined in dry transformers by using natural air cooling with the operation of an automatic fan in case of temperature rise in transformers more than the normal limits. This method is called (AN/AF).
- In case of the transformers immersed in liquids, two groups of letters must be used to describe method of cooling, the first describes windings cooling and the second describes method of cooling surface of the liquid. In case of windings immersed in oil are cooled naturally and in the same time this oil is cooled naturally by air. The letters indicating this are ONAN. If the oil is cooled by the forced air, the cooling method is ONAF. The two methods can be combined through operation of an automatic fan to force the air over the surface of the liquid in case of temperature rise more than a certain limit. This method is known as ONAN/ONAF, so the power of the same transformer can be increased significantly.
- When using a pump to help in oil flow inside the transformer in addition to operation of a fan to force the air, the method is called OFAF.
- For transformers of power 50 KVA or more the natural method of cooling ONAN requires greater cooling surface for oil tank than the normal surface of this tank. This additional surface can be obtained whether by using pipes welded to the tank walls carrying the hot oil from upper most of the tank to the bottom of the tank as used in the past or to use cooling plates similar to that used for hot water, which are installed in the form of banks at the sides of the tank to increase the cooling efficiency and decrease the cost in case of using the pipes. Now, oil tanks made from deep tortuous thin plates (1.2 mm) are used to obtain the highest natural cooling efficiency for the cooling oil of the transformers.

3-3-13 Ventilation of transformer enclosure

- The transformers used inside closed enclosure, its temperature will be higher at the same load than that used in the open air. So, to increase service life of the transformers, this matter must be taken into consideration when design transformers enclosure to limit this temperature rise.
- A balance must be made between advantages of using ventilation fans for these enclosures to limit temperature rise and the advantages of natural ventilation that does not depend on efficiency of performance and maintenance of these fans and the dangers resulted from the sudden stop of the fans.
- Temperature rise in transformers enclosures depends on the following:

(A) Transformer total losses.

(B) Net area of ventilation openings (inlet and outlet).

(C) Active vertical distance between inlet and outlet openings.

- Ideal location of air inlet opening is lower and under the center line (C.L.) of transformer radiator and to install the transformer as near as possible from it.
- Air outlet opening is at high location and must not directly over the transformer, but is located on the wall apart from the inlet opening to enable pass of the cold air over the transformer while passing from inlet opening to outlet opening.

- Minimum distance of the outlet opening from the inlet opening in the ideal case is equal to one and half height of the transformer.
- Net area of the inlet opening or the outlet opening is calculated from the following empirical formula:

$$\mathbf{A = 0.06\ P}$$

Where:

P = Total loss emitted from the transformers (KW)

A = Area (m^2)

- Fulfilling the above conditions, air temperature of transformer enclosure must not exceed the ambient temperature more than 7-8°C.

Fig (2-44) shows nomogram for determination of areas of air inlet and outlet.

Fig (2-45) shows installation of the transformers in sealed enclosure.

3-3-14 Transformers Insulation Strength

Transformers insulation strength is tested at 75 KV for the transformers installed inside the enclosures and the electrical current supply is connected through cables, and at 95 KV for the transformers installed on posts or outside the buildings and the electrical current supply is connected to them through upper lines.

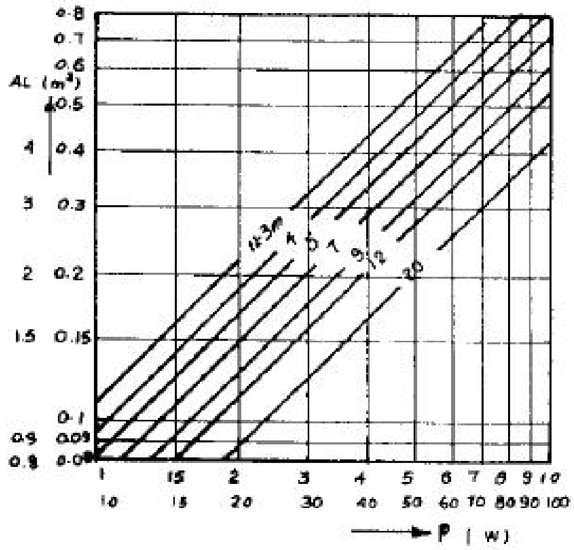
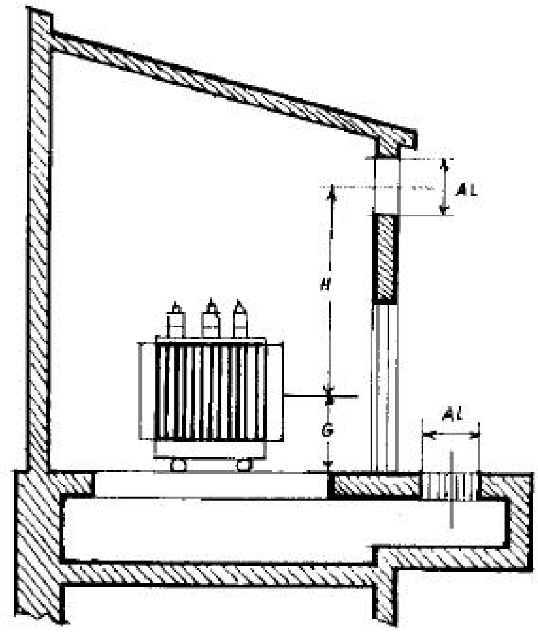


Fig (2-44): Nomogram for determination of areas of air inlet and outlet



Output KVA	63/ 100	160	250	400/ 500	630/ 800	1000/ 1750	1600/ 2000	2500
G mm	610	645	685	730	795	940	1075	1195

Fig (2-45): Installation of transformers in sealed enclosure

3-3-15 Parallel Operation of the Transformers

- Acceptable parallel operation of the transformers is that each transformer must carry its share of the rated power. To achieve this condition, the transformers connected in parallel must have the following:

- Same ratio of voltage transfer.
- Same phase shift.
- Same impedance.

Therefore, any two transformers of 3-phase transformers that have the same properties and same connection symbols can be operated in parallel (e.g. the two connections 11Yd and 11Dy can be safely operated in parallel).

The impedance controls the share of each transformer in the total load. In this case, the resistance of each unit must be symmetrical.

- There are other points must be taken into consideration such as:

A) Impedance of the transformers can be changed within ± 10% of the value of impedance test, accordingly they may exist two transformers have the same impedances according to the test although their difference in impedance of about 20%.

B) Length and type of the cable used in connection of the transformer must be taken into consideration when calculating the impedance in case of connection of new transformer in parallel if this transformer in located at location apart from the working transformers.

C) For the transformers that have division range exceeds 10%, change in impedance must be taken into consideration within this range.

In addition to above, there is great difference between transformer producers in terms of windings which give significant change in transformer properties.

3-3-16 Transformer Protection

The transformers are provided with the following protections:

3-3-16-1 Differential Protection

Differential protection depends on the comparison between the primary and secondary currents of the transformer. In case of unbalance, this means occurrence of external fault outside the transformer. As the connection of the primary and secondary windings is usually different, it must be balanced by connection of suitable current transformers (CTS).

3-3-16-2 Restricted Earth Fault Protection

Secondary windings of triple current transformers (CTS) are assembled at a side of the transformer windings with a relay connected across them. A fourth current transformer (CT) is connected on the neutral point of the windings connected in the shape of (**T**) connection. The relays are energized only in case of internal earth fault, where the output of the current transformers does not give zero sum which causes flow of current in relay circuit.

3-3-16-3 Unrestricted Earth Fault Protection

One current transformer (CT) is connected on the neutral point of the star (**Y**) windings gives measure of the earth fault protection, but the relay in this case energized also in case of occurrence of faults outside the transformer.

3-3-16-4 Over current protection

The positions of the over- current relay must be adjusted in order to be able to discriminate the protection at the load side of the transformer (and not to protect the network behind the transformer).

3-3-16-5 Gas and Oil Relay

Gas and oil relay is installed in the pipe connecting between main oil tank of the transformer and the compensation tank. It is usually exist in the oil transformers of power 1500 KVA and more. The relay is provided with two floats holding switches normally opened or normally closed. One float is operated when the oil level in the compensation tank, and consequently in the relay, reaches to undesired low level. The switch is connected usually at the low level with alarm circuit that gives alarm when the oil level in the transformer decreases. The other float is operated when there is sudden emission of gas inside the transformer in case of existence of a serious fault or burning of the transformer windings. Switch contacts in this float is usually connected to a trip circuit in the control board of the transformer, which disconnects the transformer from the source of current supply. It must take into consideration that at the start of the transform there is some gas emitting from the air bubbles exist in the oil that may energize the gas and oil relay and give false alarm.

3-3-16-6 Pressure-Relief Devices

The device in installed on the cover or the walls of the main tank of the transformer and is operated when the pressure inside the tank increases, where the seal snaps are opened and allow discharge of the collected gas through a wide nozzle with rate reaches 283 m^3/min.

3-3-16-7 Winding Temperature Indicators

As it is difficult to measure winding temperature by direct contact with the conductors of these windings, winding temperature indicator is considered the most accurate indicator through a narrow strip to load the transformer.

There are two main types of winding temperature indication:

A. Direct method: Where the device probes are put as near as possible from LV windings.

B. Indirect method: Where a thermal image device represents or simulates the temperature difference between the windings and over the oil level.

Method (A) is used in most cases with the dry transformers, where the wide cooling passages allow putting the thermal probes of the device in order not to damage the insulators of transformer windings.

- The indirect method uses a measuring structure consists of temperature indicator provided with disc and pointer and current transformer installed on the life terminal of transformer windings, where the corresponding current flows from its secondary windings to a thermal coil winded on the control winding of the measuring device. Through a calibration resistance the current flowing can be adjusted in the thermal coil to a value that produces the correct difference between the windings and the oil.
- There are other methods suitable for the large transformers, where a standard platinum resistance of value 100 ohm is used as a probe fixed as near as possible from transformer windings, and the device measures the resistance of this probe, where its value changes as windings temperature changes.
- The temperature indicators are connected to alarm circuits or disconnection circuits. They can also be connected to three or four switches to operate fans or pumps to force the air or oil to a cooling cycle outside the transformers.

3-4 Electrical Cables

3-4-1 Current Rating

* When an electrical current passes in the conductor of the cable, heat is produced in the conductor and is proportional to the heat quantity produced per unit time and the product of the current passing in the conductor and the conductor resistance.

Therefore,

$$\frac{w}{t} = I^2 R \text{ --- } (1)$$

Where:

$\frac{w}{t}$ = Produced heat quantity per unit time (W/Sec)

I = Current passing in the conductor (Ampere)

R = Conductor resistance (Ohm)

* The generated heat rises conductor temperature and produces a temperature difference in comparison with the ambient temperature of the conductor (air or ground), where the generated heat flows through the insulating material of cable conductor.

* Quantity of the flowed heat per second is proportional to the temperature difference produced from the current flow. Consequently, the temperature difference ΔT at a certain current increases in order to reach to balance in temperature at a point where the heat flow to the ambient environment per unit time is equal to the heat quantity generated in the conductor

That means:

$$\theta = \frac{w}{t} \text{ ——————————————————— } (2)$$

Where:

θ = Heat flow per second

* By applying Ohm's Law, the heat flow is calculated as follows:

$$\theta = \frac{\Delta T}{Rth} \text{ ——————————————————— } (3)$$

Where:

$\mathbf{R_{th}}$ = Thermal resistance of the conductor (thermal ohm) and is calculated in °C/Watt

The thermal resistance consists of internal thermal resistance ($\mathbf{R_{thi}}$) from the conductor to the outer surface of the cable and external thermal resistance ($\mathbf{R_{the}}$) from the outer surface of the cable to the ambient environment.

* When reaching to balance in temperature and applying formulas (1), (2) and (3), then:

$$I^2 R = \frac{\Delta T}{(Rthi + Rthe)}$$

Or:

$$\Delta T = I^2 R \quad (Rthi + Rthe) \qquad (4)$$

Note:

In case of alternating current, conductor impedance must be calculated as well as the induced currents in the metallic enclosure of the cable, but to facilitate the calculations, formula (4) can be used to give practical acceptable and sufficient results.

* Maximum allowed temperature of the conductor must be specified in the insulating materials properties used in the cables, and consequently the temperature difference between the surrounding medium of the cable and the conductor is restricted. This can be achieved only by restricting the heat generated inside the conductor. From formula (4), the value I^2R must be decreased by the following:

A. Restricting conductor resistance **R** by selecting a conductor of sufficient cross section area.

B. Restricting the allowed maximum current I_{max} at a certain cross section area of the conductor.

* Internal thermal resistance (R_{thi}) depends on the cable construction and can be calculated from cable dimensions and specific resistance of the materials used in insulation and cladding. External thermal resistance (R_{the}) of the cable depends on many external factors that have effect on the thermal convection.

* There are difficulties in specifying the current flow in the cable, not only related to the cable itself, but also to heat flow rate θ, which are the cooling problems. These difficulties can be avoided in the ordinary cables used in the economic range by specifying the allowed current by using rules applied in the normal conditions. Current rating tables are prepared for standard cross section areas of the cables and are used to find the current.

The same tables are used for LV cables regardless of the used insulating material.

* It must discriminate between two systems of laying the cables:

- Cables laid in the air.

- Cables laid in the ground.

This principal is used in cables current rating tables.

* Maximum current flow in each cross section area of the copper conductors is prepared such that the temperature difference between the conductor and the surrounding medium ΔT in normal operating conditions must not exceed 35°C, hence in atmosphere temperature of 25°C for the cable laid in air, conductor temperature will be more than 60°C for the cables insulted by P.V.C.

* Insulation material can affect cable temperature, where the temperature increases as the thermal resistance of this material increases.

LV current rating tables are prepared for XLPE insulation for maximum temperature of copper conductor of 85°C.

* Table (2-13) shows current ratings for copper cables laid in air with P.V.C insulated conductors.

* Table (2-14) shows current ratings for copper cables laid in the ground with P.V.C insulated conductors.

* Table (2-15) shows current ratings for copper cables laid in air with XPLE insulated conductors.

* Table (2-16) shows current ratings for copper cables laid in the ground with XPLE insulated conductors.

* Table (2-17) shows current ratings for multi-core cables with XPLE or PVC insulated conductors in an ambient temperature of 25°C.

3-4-2 Derating Factors

If cooling of the cable is restricted to a certain limit, the current flow in this cable must be reduced to prevent reaching to a high temperature exceeds the limits specified to the used insulation.

The factors that restrict normal cooling rate are:

Table (2-13) Current ratings for copper cables laid in air with P.V.C insulated conductors

Current rating and protection for cables laid in air with rubber, PVC or paper-insulated conductors, in accordance with NEN 1010 (2nd edition), Art. 152[1])

Nominal cross sectional area of copper conductor	Single-core cables[2])		Twin-core cables		Three- and four-core cables	
	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse
mm²	A	A	A	A	A	A
1.5	27	25	24	20	20	16
2.5	40	35	31	25	27	25
4	52	50	40	35	36	35
6	65	63	52	50	46	35
10	88	80	72	63	62	50
16	115	100	96	80	80	63
25	150	125	—	—	105	100
35	185	160	—	—	125	100
50	230	200	—	—	155	125
70	280	250	—	—	195	160
95	335	315	—	—	235	225
120	385	355	—	—	270	250
150	440	400	—	—	310	250
185	500	450	—	—	345	315
240	585	500	—	—	385	355
300	670	630	—	—	425	400
400	790	710	—	—	490	450
500	900	800	—	—	—	—
625	1040	1000	—	—	—	—
800	1200	—	—	—	—	—
1000	1360	—	—	—	—	—

Table (2-14) Current ratings for copper cables laid in the ground with P.V.C insulated conductors

Current ratings and protection for cables, laid in the ground with rubber, PVC or paper-insulated conductors, in accordance with NEN 1010 (2nd edition), Art. 153[1]).

Nominal cross sectional area of copper conductor	Single-core cables[2])		Twin-core cables		Three- and four-core cables	
	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse
mm^2	A	A	A	A	A	A
1.5	34	35	30	25	25	20
2.5	50	50	38	35	35	35
4	65	63	50	50	45	35
6	82	80	65	63	57	50
10	110	100	90	80	76	63
16	145	125	120	100	100	80
25	190	160	—	—	130	125
35	230	225	—	—	155	125
50	285	250	—	—	195	160
70	350	315	—	—	245	225
95	420	400	—	—	295	200
120	480	450	—	—	340	315
150	550	500	—	—	385	355
185	625	500	—	—	430	400
240	730	710	—	—	480	400
300	835	710	—	—	530	500
400	905	900	—	—	615	500
500	1130	1000	—	—	—	—
625	1300	—	—	—	—	—
800	1500	—	—	—	—	—
1000	1700	—	—	—	—	—

Table (2-15) Current ratings for copper cables laid in air with XPLE insulated conductors

Current ratings and protection for cables laid in air with (cross-liaked polyethylene) insulated conductors.

Nominal cross sectional area of copper conductor	Single-core cables*		Twin-core cables		Three- and four-core cables	
	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse
mm²	A	A	A	A	A	A
1.5	30	25	30	25	25	20
2.5	45	35	40	35	35	25
4	55	50	52	50	45	35
10	75	63	70	63	60	50
6	100	80	95	80	80	63
16	135	100	125	100	105	80
25	185	160	—	—	135	100
35	225	200	—	—	165	125
50	270	250	—	—	205	160
70	340	315	—	—	255	200
95	400	355	—	—	310	250
120	480	400	—	—	355	315
150	550	450	—	—	405	355
185	615	500	—	—	450	400
240	745	630	—	—	505	450
300	850	710	—	—	—	—
400	1000	800	—	—	—	—

Table (2-16) Current ratings for copper cables laid in the ground with XPLE insulated conductors.

Current ratings and protection for cables, laid in the ground with cross-linked polyethylene) insulated conductors[1]).

Nominal cross sectional area of copper conductor	Single-core cables[2])		Twin-core cables		Three- and four-core cables	
	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse
mm^2	A	A	A	A	A	A
1.5	43	35	38	25	31	25
2.5	63	50	48	35	44	35
4	82	63	63	50	57	50
6	103	80	82	63	72	63
10	138	125	113	100	96	80
16	182	160	151	125	126	100
25	240	200	—	—	163	125
35	290	250	—	—	195	160
50	360	315	—	—	245	200
70	440	355	—	—	310	250
95	530	450	—	—	370	315
120	600	500	—	—	430	355
150	690	630	—	—	485	400
185	790	710	—	—	540	450
240	920	800	—	—	600	500
300	1050	900	—	—	670	630
400	1240	1000	—	—	775	710
500	1420	—	—	—	—	—

Table (2-17) Current ratings for multi-core cables with XPLE or PVC insulated conductors in an ambient temperature of 25°C.

Number of cores	Current per core in A			
	Rubber or PVC-insulated cables		(XLPE)-insulated cables	
	1.5 mm²	2.5 mm²	1.5 mm²	2.5 mm²
6	15	21	18	25
7	14	19	17	24
8	13	18	16	23
10	12	16	14	20
12	11	15	13	19
14	10	14	12	18
16	10	13	12	17
19	9	12	11	16
24	8	11	10	14
30	7	10	9	13
37	7	9	8	11

- Increase in ambient temperature.
- Effect of the adjacent cables carrying current whether the cables laid on the walls, trays or in the ground.
- Less of moisture in the ground in which the cables are laid.
- Circumference of the cable installed totally of partially on a reel or cylinder.

In all cases, maximum current ratings in the tables must reduced by a certain percentage.

* Table (2-18) is used as a practical guide for derating factors for rise in ambient temperature, effect of grouping of cables, variation of thermal resistivity of the soil due to changing in moisture percentage and for cables on reels.

* In case of existence of more than one affecting factor at the same time, the derating factors must be taken into consideration corresponding to these effects. .

* Precaution must be taken in case of installing more than one cable in the same trench or duct, where it is difficult to provide sufficient ventilation and specifying accurate derating factor.

3-4-3 Voltage Drop

The voltage drop in the cable is the difference between the voltages measured at the two ends of the cable.

Drop percentage of the circuit voltage rating is:

- Maximum 5% for lighting system
- Maximum 2% for power system.

Table (2-18) Practical guide for derating factors for rise in ambient temperature, effect of grouping of cables, variation of thermal resistivity of the soil due to changing in moisture percentage and for cables on reels

Derating factors for the variation in ambient temperature exceeding 25 °C.

temperature			25 °C	30 °C	35 °C	40 °C	45 °C	50 °C	60 °C	70 °C
derating factor	XLPE	f1	1.00	0.95	0.91	0.87	0.82	0.76	0.65	0.50
derating factor	PVC	f2	1.00	0.93	0.85	0.76	0.65	0.53		

Derating factors for grouping of cables laid in air

number of cables			2	3	4	5	6
clearance equal to cable diameter	XLPE and PVC	f3	0.94	0.90	0.87	0.85	0.83
cables laid side by side without interspace	XLPE and PVC	f4	0.81	0.79	0.77	0.75	0.73

Derating factors for grouping of cables laid direct in the ground (depth appr. 70 cm, distance between the cables appr. 10 cm)

number of cores and cross sectional area of the conductor				number of cables							
single core	three and four cores			2	3	4	5	6	7	8	9
95 mm² and less	35 mm² and less	f5	XLPE and PVC	0.90	0.82	0.78	0.74	0.72	0.70	0.68	0.66
120/300 mm² incl	50 and 70 mm²	f6	XLPE and PVC	0.89	0.80	0.75	0.71	0.68	0.66	0.64	0.62
400 mm² and more	95 mm² and more	f7	XLPE and PVC	0.87	0.78	0.72	0.68	0.64	0.62	0.60	0.58

Derating factors for variations in thermal resistivity of the soil

specific heat resistance of the soil in °C.cm/W			50 (damp)	100	150	200 (very dry)
derating factor	XLPE and PVC	f8	1.0	0.8	0.7	0.6

Derating factors for cables on reels

number of layers on reels			1	2	3	4	5
derating factor	XLPE and PVC	f9	0.50	0.38	0.32	0.27	0.24

* Accurate voltage drop can be calculated from the circuit vector diagram, and in most cases the accurate calculation is not necessary and it is sufficient approximate calculation as follows:

A) For DC

$$\Delta \upsilon = 2.I.l \quad \frac{r}{1000}$$

Where:

$\Delta \upsilon$ Voltage drop between the two ends of the cable in volt (measured between the poles)

I = Current rating in Ampere.

l = Cable length in meter.

r = Cable resistance in ohm/km

B) For single phase AC

$$\Delta \upsilon = 2.I.l. \frac{r \cos\phi}{1000}$$

$\Delta \upsilon$ Voltage drop between the two ends of the cable in volt (measured between the phase and the neutral point)

I = Current rating in Ampere.

l = Cable length in meter.

r = Cable resistance in ohm/km

Cos φ = Power factor of the cable load.

C) For three phase AC

$$\Delta \upsilon = \sqrt{3} \quad \frac{r \cos\phi}{1000}$$

Where:

$\Delta \upsilon$ Voltage drop between the two ends of the cable in volt (measured between the conductors of the same phase)

I = Current rating in Ampere.

l = Cable length in meter.

r = Cable resistance in ohm/km

sin q = Power factor of the cable load.

Note:

The above values are sufficiently accurate when the impedance of the cable (χ) can be neglected compared with cable resistance (r), which is the normal case of cables with cross section area not more than 70 mm^2.

For cables with greater cross section area, the voltage drop is calculated as follows:

(1) For single phase AC

$$\Delta\upsilon = 2.I.l. \frac{r\cos\phi + \chi\sin\phi}{1000}$$

(2) For three phase AC

$$\Delta\upsilon = \sqrt{3}\ .I.l. \frac{r\cos\phi + \chi\sin\phi}{1000}$$

Where:

χ is cable impedance in ohm/km

Can be taken 0.1 ohm/km

* The nomograms shown in Fig (2-46) and Fig (2-47) are used for practical applications.

3-4-4 Cables short circuit

3-4-4-1 Thermal short circuit rating with PVC insulted

Thermal short circuit rating is calculated from the following formula:

$$Ik = \frac{109}{\sqrt{t}}\ .q$$

Where:

IK = Short circuit rating in KA

t = Short circuit time in second

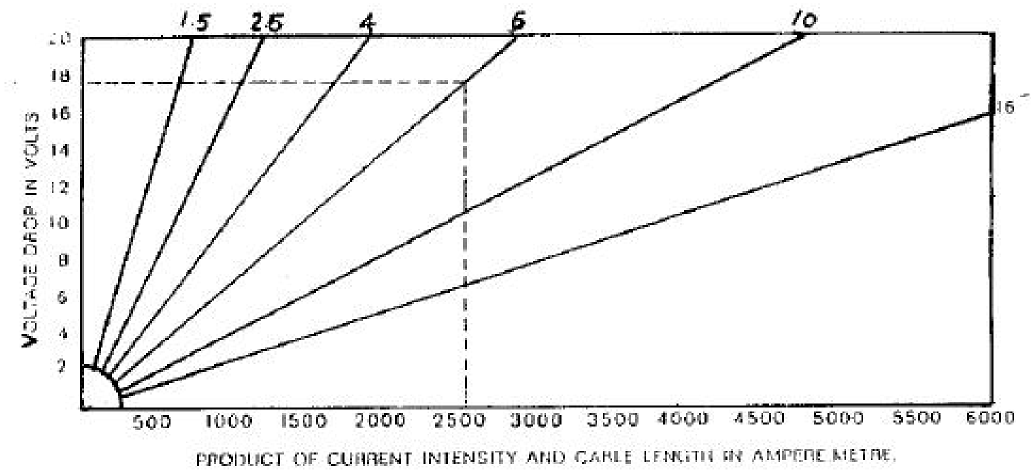


Fig (2-46): Nomogram for calculation of voltage drop for double cores cable, single phase alternating current, Cos φ = 1.0

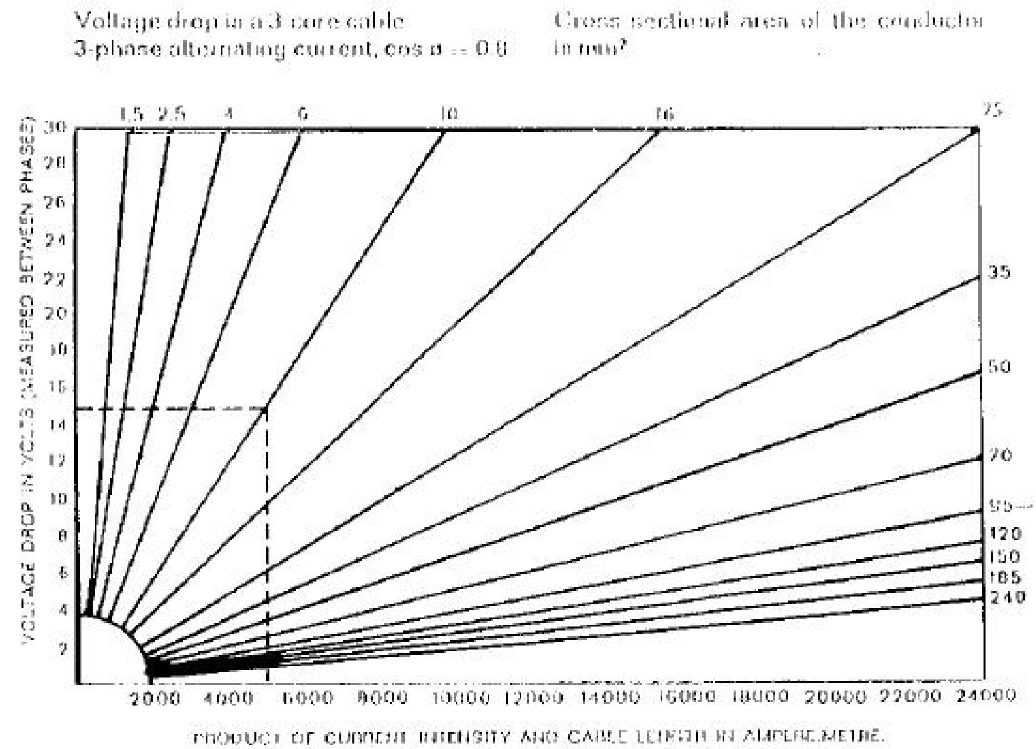


Fig (2-47): Nomogram for calculation of voltage drop for 3- core cable, 3- phase alternating current, Cos φ = 0.8

q = Nominal cross section area of the copper conductor in mm^2

This formula is applicable for temperature rise between (70-150) °C

Fig (2-48) shows nomogram the relation between the short circuit, time and the cross section area of the cables with PVC insulated conductors by applying the above formula.

3-4-4-2 Thermal short circuit rating with XPLE insulted

Short circuit is calculated from the following formula:

$$Ik = \frac{\sqrt{t}}{144} \cdot q$$

Where:

IK = Short circuit rating in KA

t = Short circuit time in second

q = Nominal cross section area of the copper conductor in mm^2

This formula is applicable for temperature rise between (85-250) °C

Fig (2-49) shows nomogram the relation between the short circuit, time and the cross section area of the cables with XPLE insulated conductors by applying the above formula.

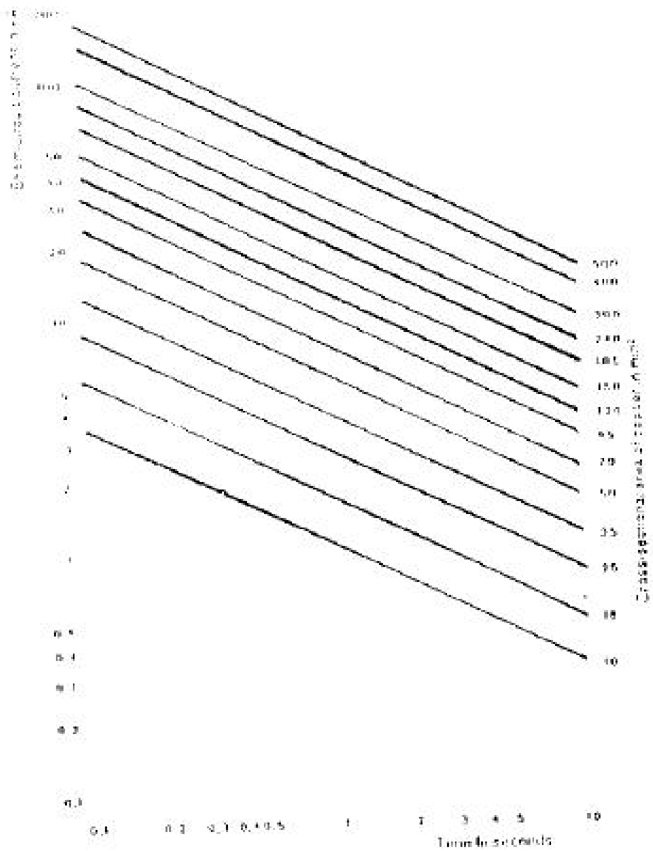


Fig (2-48) Nomogram the relation between the short circuit, time and the cross section area of the cables with PVC insulted conductors (LV copper conductor cables)

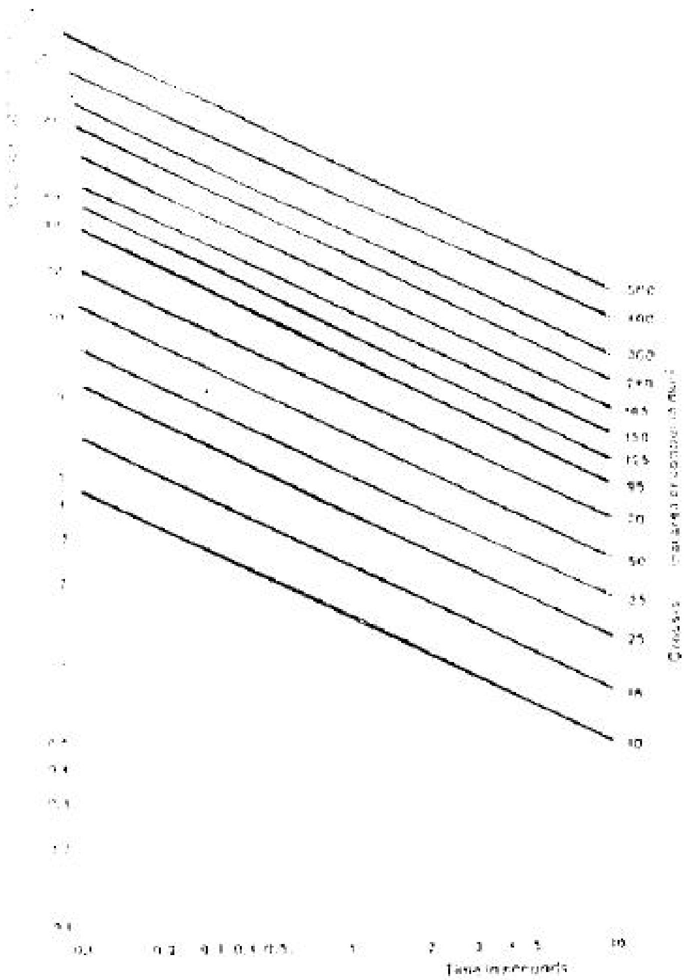


Fig (2-49) Nomogram the relation between the short circuit, time and the cross section area of the cables with XLPE insulted conductors (LV copper conductor cables)

3-5 Electrical Power Generation Station

3-5-1 Introduction

For the importance and necessity of continuous lift of the pumping station in case of current interruption from the city supply to the station, it must provide alternative power supply to the plant by construction of emergency electricity generation station as integral part of the plant for continuous operation purpose.

3-5-2 Power of the emergency power station

Emergency power station must have a power commensurate with the operation of all pumps and operating devices in the pumping station.

3-5-3 Number of units of emergency power station

According to the above mentioned emergency power for operation of the pumping station, minimum number of the generation units shall be determined to achieve balance between economic aspects and secure of operation taking into consideration the available area.

3-5-4 Specifications of Generation Unit Motors

Power : Emergency power / number of generation units.

Cycle : Four strokes

Fuel : Diesel/ solar with sprinklers, fuel pump and turbo charger.

Cooling : Water or air according to the location of the station and the availability of the cooling water.

Starter : Electrical or compressed air

Cylinders order : According to the power and the available area, row of V type will be selected.

Engine Speed N : Engine speed in specified in rpm according to current frequency (f) (50 c/s) and number of poles of the electrical generator (P) by the following equation.

$$f = \frac{P.N}{60} \quad Hz$$

Motor speed is taken as follows:

Less than 300 KW	: 1500 rpm
More than 300 KW up to 600 KW	: 1000 rpm
More than 600 KW up to 1500 KW	: 750 rpm
More than 1500 KW	: 600 rpm

3-5-5 Diesel Motor Components

Motor Intake

- Air requirements are estimated by 0.07 m^3/min/hour brake of the motor power.
- Air intake is provided by internal air filter.
- When using turbo charger, it must provide a straight length not less than 5 cm before connection it with the motor air intake.

- Air pipe connections must be designed in a way that facilitates replacement of the filter in addition to isolation of motor vibrations and noise.

Engine Exhaust

- Exhaust pipes and the silencer must be thermally insulated to protect the workers in generation house and prevent temperature rise in the house that may affect intake air temperature or starter batteries.
- Path of the exhaust pipes must be kept away from any flammable materials by a distance not less than 25 cm.
- Exhaust pipes must pass inside enclosure of diameter not less than one and half exhaust pipes diameter when passing through the walls or the ceilings.
- End of the exhaust pipes must be chamfered at angle from 30° to 45° to reduce formation of gas cyclones, reduce noise and protection from rains.

House Ventilation

- Generation units' house must be ventilated, as the good ventilation saves from 6% to 10% of fuel consumption due to the heat dissipation in the house, improves production of generation units and distribution boards and provide suitable atmosphere for operation and maintenance works in the house.
- Ventilation of the house must be kept at 38°C.

Engine Cooling

- Cooling cycle must contain thermostat allows operation over 80°C to keep the motor efficiency at starting up.
- Temperature difference between inlet and outlet cooling water must be between 5°C to 8°C.
- Cooling water pressure must be between 0.25 to 0.45 kg/cm^2 to prevent formation of vapor inside the radiator and engine cooling chest.
- Temperature of the upper part of the radiator must be less than 100°C to prevent confinement of cooling water pump and increase its efficiency.
- Speed of pure cooling water is between 0.6 m/sec and 2.5 m/sec, while it is from 0.6 m/sec and 1.9 m/sec in case of raw water.
- Quality of cooling water (pure or raw) must be taken into consideration when determining the velocities inside cooling cycle pipes.

3-5-6 Fuel System

Main Storage

- Fuel is stored in large tanks with sufficient volume for operation of all generators at full load for a period ranging from one week to two weeks continuously according to the distance from supply sources.
- Main fuel tanks may be under or over ground surface.
- Fuel tank is made from treated steel plates and not from galvanized iron to avoid chemical reactions with the fuel.

- Main tanks must be over ground surface in case of availability of the necessary area away from the surface motion and under the ground surface in case of unavailability of the necessary area.

Tank Components

- Tank filling pipe installed in a way that achieves safe operation processes.
- Tank vent pipes.
- Measuring hole.
- Drain valve at the bottom of the tank to suck the sediments at regular intervals.
- Electrical pumps to transfer fuel from main tanks to daily tanks.
- Tank components are made from treated steel (and not galvanized iron), steel or copper.

Daily Storage

- Daily tank is installed in generators house.
- Fuel suction and return pipe diameters must not less than motor components and pipes diameters for the all pipe lengths.
- Pipe diameters are increased in case of supply fuel to more than one motor, and also in case of temperature decrease.

Filters

- Filters are installed to prevent fuel sediments which cause blockage of the fuel injection sprinkle nozzles and injection pumps.
- Filters are provided with grid screens with spacing 0.3 mm.
- Large motors are provided with two filters with a means of change of any of them to facilitate cleaning and replacement of the damaged filter during operation to avoid fault of the motor.

3-5-7 Starting Systems

The generator motor is started by one of the following two methods:

- Electrically (battery + starter motor) for motors up to 600 K.W
- Compressed air.

Electrical Starting motion

The following points must be followed when using this method:

- It is preferred to use lead acid batteries because they are less expensive than the nickel cadmium batteries.
- Generators house temperature must not exceed 38°C to maintain the power and operation efficiency of the batteries.
- Copper cables must be used in the connections between the batteries and starter motor.
- Battery charger must be used in generators house to charge the batteries during stop operation of the generators, in addition to the DC generator which charges the batteries during operation of the engines.

Starting motion by compressed air

The following must be taken into consideration when using this method:

- Provision of air compression ranging from 7 kg/cm^2 to 16 kg/cm^2 from the an air compressor, air tanks and non-return valves between them.

- Volume of the air tanks must be selected according to air quantity necessary for each operation, number of operations, tank pressure and atmospheric pressure. This volume is determined by supplier of the engines.
- The main air compressor is operated by internal combustion engine turned by benzene, kerosene or solar.
- Provision of an emergency air compressor operated by electrical motor.

4- Design rules for construction and architectural works

4- Design rules for construction and architectural works

4-1 Architectural Works:-

4-1-1 Layout:-

Units must be distributed on the site layout of the pumping stations in a way that allows the provision of the following rules:-

1. Main roads and sub-roads must be with the width that allows entrance and exit of the cars and to perform the necessary maneuvering, taking into consideration levels of the roads and sidewalks with the constructions that will be implemented.
2. Existence of the guard rooms and information room adjacent to the main entrance of the plant.
3. Provision of green areas between the units.
4. Plant units must be coordinated in a way that allows easy motion inside the plant between the different units.
5. Administrative building units must be away from treatment units and to study wind direction to avoid subjection of the buildings to bad smells and gases.
6. The site must be provided with water, irrigation, fire, sanitary drainage, electricity and lighting networks.
7. Provision of parking areas.
8. Construction of suitable fence provided with guard towers and lighting.

4-1-2 Project Units:-

The following are the design rules for some units that consider the aesthetical aspects (color and heights coordination of project units):-

4-1-2-1 Pump House:-

- Easy electricity supply taking into consideration the economic aspects.
- The distance between crane beam and the lowest point of ceiling beam must be appropriate so that it cannot hinder safe operation especially if there is a crane with horizontal movable vehicle.
- Provision of sufficient ventilation and lighting inside the house.
- Provision of handrails around sump roof openings inside motors house.
- Cable trenches must be submersed in the floors.
- Pump house floor must be from ceramics resistant to acid and friction and the walls from faience at suitable height.

4-1-2-2 Generator and Transformers Building:-

- Specifications and dimensions of the building must be in conformity with Ministry of Electricity conditions.

- Easy access to transformers building doors at the external fence and at the main roads and sub-roads.
- Suitable distance between crane beam and the lowest point of ceiling beam.
- Provision of sufficient ventilation and lighting inside the house
- Internal finishing must be from materials suitable to the building. Floors must be from ceramics resistant to acids and friction and cable trench covers at the ground level to not hinder the motion.

4-1-2-3 Workshops and Stores:

- The distance between crane beam and the lowest point of ceiling beam must be appropriate.
- Provision of sufficient ventilation and lighting inside the house
- Easy access of cars, equipments and instruments to workshops and stores entrance.
- Near from workers rest room and toilettes.
- Internal finishing must be from materials suitable to the building. Floors must be from ceramics resistant to acids and friction and cable trench covers at the ground level to not hinder the motion

4-1-2-4 Chemicals and Chlorine Building

- Easy access of cars carrying equipments, chlorine cylinders and maintenance tools

- Anti- chemicals finishing materials must be used by laying ceramics on the floor resistant to acids and the walls from faience with suitable height not less than lower threshold of the windows.
- Cylinders iron bases must be provided with four iron rollers for each cylinder such that the bases are at 1 m distance form the side walls to facilitate motion and adjust position of the cylinders and the valves on correct operation position.
- It is recommended to provide the building with upper cranes (monorail) at a suitable distance between the crane beam and the lowest point on the building beam for each row of cylinders such that it is not intersecting with the falling beams at the entrance of chlorine store with the path of crane beam and at suitable height for easy handling of cylinders from surface of the cars.
- Crane beam must be extended to suitable distance allows for safe loading and discharge.
- Good design for acoustic soda of neutralization for easy of periodic detection.
- Concrete ducts with covers must be constructed for easy removal and path of chlorine injection pipes made from PVC of similar.
- The store must be provided with ventilation holes provided with mechanical ventilation devices (air suction fans) of height not more than 50 cm from building floor. The hole must not less than 35 × 35 cm and the distance between each two holes is nor more than 2 m.

- In case of existing of neutralization chamber of leaked chlorine gas, door opening must be from the rear of the house and height of the suction fans from the side of the cylinders house and at the same level of operating cylinder valves.
- Provision of suitable lighting and ventilation for the building and ducts for washing water drainage.
- The following conditions must be provided for base of the neutralization tower base:-

• Must be of height not less than 2 m from chlorine building floor.
• Internal walls must be treated with anti-acid materials.
• Upper hole of the tower must be lined by rubber material to prevent air leakage.

4-1-2-5 Administration and lab building:

- Must be near from the main entrance for easy control of workers and access to different buildings and facilitating sampling manually or by special pumps and devices.
- Study wind direction to avoid subjection of the buildings to bad smells and gases with the provision the lab with a tower to drain the gases.
- Provision of sufficient ventilation and lighting inside the unit.

- Floors must be from ceramics resistant to acids and walls from faience
- Provision of upper side holes for installing suction gas fans such that level of thee holes is less than level of lab ceiling by a sufficient distance.
- Provision of sanitation installations for the basins (water- sanitary drainage)
- Discs surfaces must be covered with natural marble or ceramics or similar.
- It is preferred the lab to be at the ground floor in case of being constructed with the administration building with separate entrance and to be divided into number of sub-labs such as chemical, bacteriological, biological and physics labs, washing room, balances room and offices for chemists and supervisors.

4-2 Construction Works

Refer to Egyptian Codes concerning construction works.

5- Preparation of Tender Documents

5- Preparation of Tender Documents

5-1 Introduction

Released tender documents must contain technical information of the project, general and special conditions, which are the provisions referred to them contract parties, if necessary.

5-2 Contents of tender documents

Tender documents contain the following volumes:

- General and special conditions and technical specifications.
- Estimated bill of quantities
- As built drawings.
- Any other documents prepared by the designer, such as borings report, analyses of soil and groundwater.

5-2-1 General and special conditions and technical specifications of the project:

This volume shall contain:

(A) Invitation to tender.

(B) Tender form.

(C) Instructions to bidders.

(A) Invitation to Tender

Invitation to tender will be in one or two pages with brief description about the project and tender procedures. It also contains method of obtain copy of tender documents, price, date and place of submitting these documents. The tender is published in the daily newspapers (two widely spread newspapers) in two consecutive days.

(B) Tender Form

Tender form determines standard format for the contractors to submit their prices and offers to the employer which facilitates technical and price comparison works for equal opportunities.

(C) Instructions to Bidders

Instructions to bidders are the standard base of the bids that help to arrange bid contents in standard order according to tender form. These instructions shall cover the Following:

- Definitions.
- Offer of bidders.
- Tender documents.
- Tender procedures.
- Tender requirements.

- Mail instructions.
- Primary and final insurance
- Contract form between the owner and the contractor.
- Additional instructions.

5-3 Insurance Forms

Tender documents contain format for primary insurance submitted with the bid and the final insurance that shall be submitted by the winner contractor from approved bank. The format shall contain a provision states that the employer has the right to issue this insurance for his benefit at first statement from the bank in this regard without any objection from the contractor. This insurance must be valid to cover its purpose.

5-4 Contract between the owner and the contractor

This contract is considered an independent document and shall cover five main principals as follows:

- Legal capacity and competence of the parties to act and conclude the contract. Sufficient number of copies must be signed for the owner, contractor, the engineer (if any), contract and purchasing department and state counsel.
- Clear brief description of the project.

- Expected implementation period. This part is very important, as according to it fine delays or contract extension, etc. may be imposed.
- The price, whether a fixed price covers the entire project, price for each item of works or LS price for each group of similar items of the works, as agreed upon.
- Terms of payment through periodic payments according to work progress and what agreed upon such as deduction of certain percentage accumulated until the preliminary handover, the deduction from the advance payment paid to the contractor, etc.

In addition to the closing payment of the project, this is considered from the most important legal payment during the project.

This contract contains also to what extend the relation between this document and other tender documents in terms of legal capacity, as this document is the only one signed by contract parties.

5-5 Contract Conditions

Conditions of the contract are divided into two parts: general conditions and special conditions (completing conditions).

5-5-1 General Conditions

General conditions cover rights and obligations of both the owner and the contractor and determine scope of work and responsibilities of the consultant who supervises the implementation (if any), works and responsibilities of project manager.

Contents of general conditions are:

A- Definitions

Important items are defined accurately and clearly, such as:

The owner- The contractor- Subcontractor- The engineer- The works- The Project- Tender documents- drawings- Completion date of the project- Project commence Date.

B- Rights and Responsibilities

Rights and responsibilities of each party are explained in detail to know each party his rights and responsibilities under the contract as well as the relations with the sub contractors, where rights and responsibilities of the contractor extend to them.

C- Using others

In general, the owner has the right to perform some works of the project by himself or by independent contractor.

Therefore, the problems resulted from overlapping or efforts cooperation that affect works of other must be added and detailed in the general conditions.

D- Settlement of Disputes

Conditions shall be laid in detail to determine method of settlement of disputes resulted from the work whether amicably or by arbitration.

E- Duration of the project

Project start up date and completion date is determined and accordingly the period necessary for execution of the project. On the basis of this, the contractor shall make the time schedules necessary for completion of the project to be approved from the owner or his representative. According to these schedules shall specify any delay in works, its reasons and to what extend the contract needs to amend the time schedule according to the delay or to impose delay fines, as the case requires. The force Majeure must be specified for the circumstances out of control of the management during which the work is stopped. It must also specify working hours, official holidays and occasions for the contractor to be aware in this regard.

F- Payments

Payments will be prepared according to work progress in a defined and clear way, date of submitting these periodic payments and its least value, period necessary for their revision by the owner or his representative in technical and financial affairs and return procedures of these payments in case of mistakes in different stages of revision.

Also must state that approval of the owner for issuance of these dues does not consider approval of acceptance the work.

Also must state that the contractual and legal reasons that allow to the owner to seize and hold issuance of contractor dues against failure to repair the defected works, claims filed from the third party and failure of the contractor to comply with conditions and provisions of the contract.

When all works are completed, final payment is made, after submitting the quittance certificate by the contractor to the owner proving that he has fully received his financial dues, and he shall not make any claims against the owner in whatsoever form. Often, an agreement between the owner and contractor is made to waive all lawsuits raised against each other before approving final payment.

G- Procedures of preliminary and final handover:

(1) Preliminary Handover:

- Preliminary handover of the project shall be as follows:

- After completion of works, the contractor or his representative shall notify the owner in writing that all works are under operation and ready for commissioning procedures which shall be performed by the contractor in the presence of the owner or his deputy and the engineer who supervising the execution (if any).
- After successful commissioning and supply of the spare parts, auxiliary devices and as built drawings by the contractor, this must be proved in project commissioning report.
- After stability of the commissioning during the necessary period agreed upon between the owner and the body that shall take over the project for operation and get benefit thereof, or if the contractor shall perform the operation for certain period under the contract.
- In case of failure of the commissioning, the contractor adheres to repeat the commissioning at his own expensive under performing successful commissioning during the necessary period.
- Preliminary handover is performed to get benefit and operate the project and note any remarks or unimplemented works by making remarks list provided that these remarks have no effect on operation and getting benefit from the project. If the contractor failed to supply any auxiliary devices, spare parts, preparation of drawings or documents, the contractor undertakes to complete them within an agreed period. This period is within warrantee year.

- The owner has the right to deduct or hold any amounts from the dues of the contractor against completion of these works or continuation of the guarantee letter. These amounts will be returned to the contractor after completion of these obligations.

- If any part is defective or damaged during guarantee year, the contractor shall replace the defective or the damaged part or perform repair if there is benefit from the repair. If the contractor fails to perform the repair, the repair will be performed by deducting the cost from his dues or according to the provisions of the contract in this regard. Warrantee of the replaced part extends to one year from date of replacement.

2- Final Handover:-

- Before the end of warrantee period and the contractor has completed all of his obligations, the contractor shall notify the owner in writing to specify date for inspection and form final handover committee to include the owner and the body benefited from the project which was trained on operation and maintenance during the warrantee year, and the contractor and consultant (if any).
- In any works or obligations are not completed, final handover is postponed until the contractor fulfills all the obligations according to the contract, technical conditions and workmanship. The warrantee period will be extended accordingly.
- If the inspection proved that the works are in conformity with original technical conditions and specifications or amendments thereof that added during execution of the project and the committee decided that the contractor has completed all of his obligations, final handover report shall be issued and signed by the contractor, beneficiary body that shall be responsible about future operation and the engineer (if any).
- This final handover does not prejudice the responsibility of the contractor under Egyptian civil law.
- After completion of the final handover, a closing payment is made between the owner or his deputy and the contractor or his representative, and according to what is included in item (F-1-5-4)

H- Insurance

The general conditions determine the areas that must be covered by the insurance for the works, workers and the third party against the risks, including accidents, theft, fire, etc by an insurance company approved from the owner. The insurance certificates are issued in the name of the owner and shows also suitable compensation for each case. It also covers owner, contractor and third party obligations. Insurance certificates are sent to the two parties of the contract.

I- Changes

The general conditions determine method of making the change orders of works that change in the contract and the time period necessary for this change by addition of deletion from contract duration without affecting the contract agreement itself.

The general conditions also determine method of negotiation between the different parties to agree upon the effects resulted from the change in terms of time and cost.

G- Correction of works

This item of the general conditions gives the right to the owner to reject the defective or unconformable works to terms of contract that must be replaced or repaired by the contractor at his own expense.

K- Contract Termination

The general conditions must contain an item that gives the right to the owner to terminate the contract due to failure of the contractor to complete the works on the specified time or non-execution of the works.

It gives also the contractor the right for termination in case of failure of the owner to fulfill his obligations.

5-5-2 Special Conditions

The special conditions are completing the general conditions to conform to the local laws, environmental conditions and special conditions of each separate project. Item numbers of these conditions are similar to what in the general conditions when adding or deleting some provisions of the general conditions.

5-5-3 Drawings Album

A- Drawings

The drawings express the relation between different components of the construction, where they illustrate their locations and dimensions and contain information about the sizes, locations and quantities, which means design drawings.

The drawings must be complete to a large extend, accurate, with suitable scales and include sufficient dimensions. They are considered guide for the contractor in his estimations and calculation of the quantities when preparing the bid, construction and execution of works. They also contain separate working drawings for all constructional, architectural, internal sanitary drainage, electricity, conditioning and cooling works.

B- Shop Drawing

As the working drawings do not contain accurate details for each part of the different components of the construction, the executor (contractor, subcontractor, supplier, manufacturer, etc) must prepare accurate and clear shop drawings contain all the detailed information necessary for execution, including graphical curves for method of performance, spare parts lists for the components, method of installation and method of operation that shall be approved and used.

C- As Built Drawings

The contractor shall prepare drawings complete with accurate dimensions and details according to what actually executed on the ground to be submitted to the owner as documents kept as a reference for maintenance and operation works.

5-5-4 Technical Specifications

Technical specifications are completing the shop drawings, where they express the requirements in words and shows quality of the materials, supplies, equipments and technical construction methods.

Technical specifications are considered the greatest part of the contract according to the following categories:

General requirements, site works, concrete works, masonry works, metal works, wood works, insulation and protection, doors, windows, finishing, special works, equipments, furniture, special construction, conveying systems, mechanical works and electrical works.

These works are divided into four sections:

- General, materials, execution and method of calculation.

"**General**" section contains definition of the scope of work in this section, including quality control, information about the supplies and equipments, handling and storage requirements and warrantees.

"**Materials**" section contains brief description of the materials used in this section as a guide for the producers. "**Execution**" section contains details of methods of construction, performance of works, inspection, acceptance and tests. "**Calculation**" section verifies if this party of the works are loaded on contract items, item price, LS, etc.

5-5-5 Estimated Bill of Quantities

- Estimated bill of quantities contain work items, brief description of each item, method of calculation, whether with unit of area, volume or LS, and the estimated quantity of each item.
- The contractor shall price each item.
- In bill of quantities, if the contractor did not price an item, the price of this item is loaded on the prices of the other items of the contract upon execution, however specifying the highest price for this item in the other offers when evaluating this offer by evaluation committee.
- The quantities listed in the bill of quantities are estimated and the owner is entitled to increase or decrease these quantities by 25% with the same contract prices, and the quantities that exceed this percentage, their new prices shall be agreed upon.

Chapter 3: Implementation Conditions

1. Project implementation management

2. Site planning and preparation

3. Civil and architectural works

4. Mechanical and Electrical Works

5. Electrical Works

6. Tests

7. Performance Tests and Handing Over

1- Project Implementation Management:

Success of any project is measured by its completion on time according to contract documents, technical conditions, specifications and shop drawings.

The access key to project success is the provision of continuous communication and explanation means between the parties working in the project through a relation between project owner, consultant and contractor that helps execution of the works according to the time schedules specified for completion of this project.

Volume of labor required to complete the project depends on volume and condition of each project. Fig (3-1) illustrates organizational structure of project management.

For good coordination between the three parties, the following system shall be followed:

A. Project owner shall contract with the contractor entrusted to execute the contract according to the applicable rules and laws.

B. Project owner shall form execution unit for technical revision of all execution steps and know the obstacles and problems and provide their technical, financial, administrative and legal solution.

C. The execution unit shall coordinate with the project consultant who performed studies and design works and preparation of contract documents for supervision of execution.

D. Chairman will be appointed for the execution unit (project manager) to coordinate between the staff inside the unit and put work rules for the relation between the execution unit and the consultant.

E. Project consultant shall coordinate between owner, contractor and consultant works. Fig (3-2) shows project execution unit and specifies its responsibilities as follows:

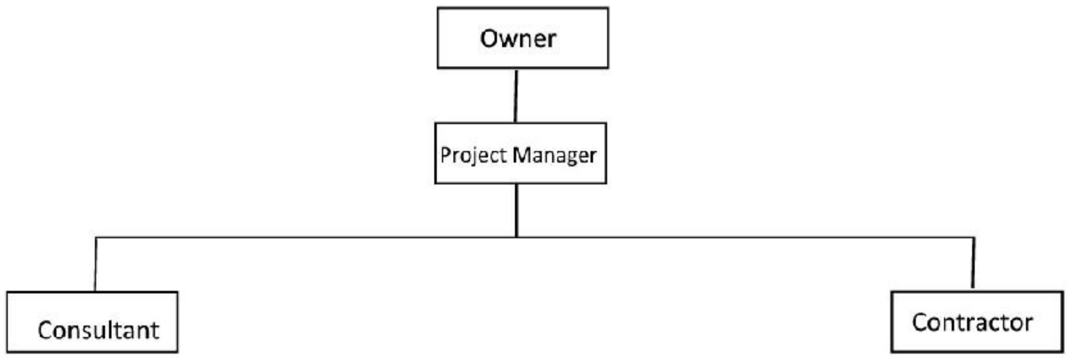


Fig (3-1): Organizational Structure of Project Management

Execution Unit

Project Manager

Financial and Administrative Affairs

Technical Affairs

Fig (3-2): Project Execution Unit

1-1 Project Manager:

A. Competent and can act to manage the project.

B. Responsible about supervision of execution all works and activities and has the authority to control, familiarize and coordinate between different technical, financial, administrative and legal activities.

C. Select the ideal method to execute the works and take into consideration the economic aspects, time and effort to achieve the objective towards completion of the project on a timely manner and take the measures needed to correct the course of implementation to complete the project successfully on time within the limits of the available funding.

D. Project manager shall select the technical manager and financial and administrative affairs manager and authorize them to form and approve the assisting staff for both of them.

E. Approve issuance of consultant dues under the contract.

1-2 Technical Affairs:

1-2-1 Design Engineers:

Revision works of the drawings submitted from the consultant office shall be conducted by specialized engineers for conformity of the hydraulic, architectural, civil, mechanical and electrical drawings and ensure availability of sufficient number of shop drawing copies.

1-2-2 Execution Engineers

A. Execution works will be conducted by specialized engineers in different specializations to follow up execution stages.

B. Prepare periodic reports about work progress, revise and sign daily follow up records by the consultant and the contractor and list any technical remarks or problems that may hinder progress of execution.

C. Revise and compare the periodic payments according to the actually executed quantities with the shop drawings and the records submitted from the contractor and approved from the consultant.

1-3 Administrative Affairs:

1-3-1 Financial and Administrative Manager:

A. Specialized accountant shall be appointed to perform this work in terms of financial and administrative aspects of the project and shall provide assistance and advice to the project in his scope of work.

B. Shall follow up project financial and administrative works; submit periodic reports to the project manager and proposals on how to solve the financial and administrative problems that object progress of work.

C. Shall select financial and stores audit staff.

1-3-2 Financial Audit:

Specialized accountants shall be appointed to perform the following works:

A. Review the payments from an accounting point of view and conformity of the rates with the contracts.

B. Follow-up the financial position of the project up to date and maintain records that indicate the amounts available, what has been disbursed and the remaining.

C. Compare expenditure with the execution timetable.

1-3-3 Stores Accounting

Specialized accountants shall be appointed to perform the following works**:**

A. Maintain regular records show all the supplies, their dates of supply and value.

B. Review the supplied equipments according to the contract on the packing lists.

C. Maintain regular records about the adjustments of each documentary credit.

1-4 The Consultant

Responsibilities of the consultant are determined in the following:

A. Prepare typical report forms, methods and procedures of work progress.

B. Prepare rules to control how to sound managing of the project within its actual budget.

C. Select high efficient technical supervision team in different specializations.

Fig (3-3) shows organizational structure of the consultant.

1-4-1 Technical Supervision

A. Follow up the daily works being carried out by the contractor and take the necessary samples for test.

B. Follow up the execution situation and its conformity with the approved execution schedule.

C. Review and approve works counting books submitted from the contractor

D. Review the submitted payments from the contractor and approve them for issuance.

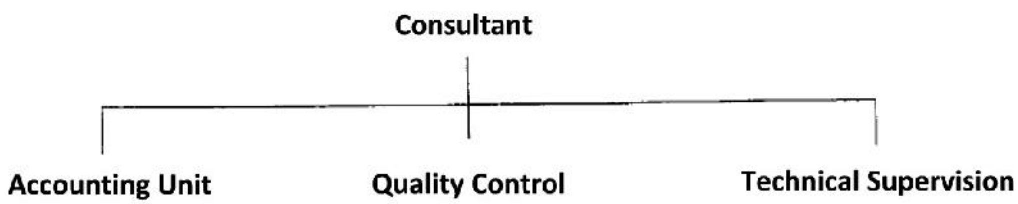


Fig (3-3): Consultant Organizational Structure

E. Study any additional works or amendments required for implementation of the works to take the full advantage of the project and to be presented to the project manager for approval.

F Study any claims submitted from the contractor whether they are financial or regarding any amendments in execution period of the project after the contractor has fulfilled all the documents necessary to prove his rights in these claims and present the result to the project manger.

G Participate in preliminary and final handover works and prepare list of remarks that does not prevent the preliminary and final handover.

1-4-2 Quality Control

A. Ensure fitness of equipments and supplies materials supplied to the site, revise test certificates and perform the necessary tests on random samples of materials and equipments to ensure their conformity to the specifications stipulated in the contract.

B. Supervise preparation experimental concrete mixes, follow up their treatment and test to determine their breaking strength according to the value specified by the designer and stipulated in contract documents.

C. Perform supervision and periodic follow up works on pouring and treatment of the executed concrete constructions.

D. Ensure calibration of the devices used in test and measurement works.

1-4-3 Accounting Unit

It performs the following:

A. Revise the payments submitted from the contractor.

B. Follow up project financial situation.

C. Revise expenditures and revenues of the consultation office.

1-5 The Contractor

Responsible about execution of all works until completion of the project successfully and shall have efficient stuff in different specialization areas as follows:

Fig (3-4) shows organizational structure of the contractor.

1-6 Resident Engineer

He is responsible about the following:

A. Management of the project.

B. Coordinate between his assisting staffs and specify their duties.

C. Revise the executed works through time schedules, revise and approve the payments prepared by executing engineer.

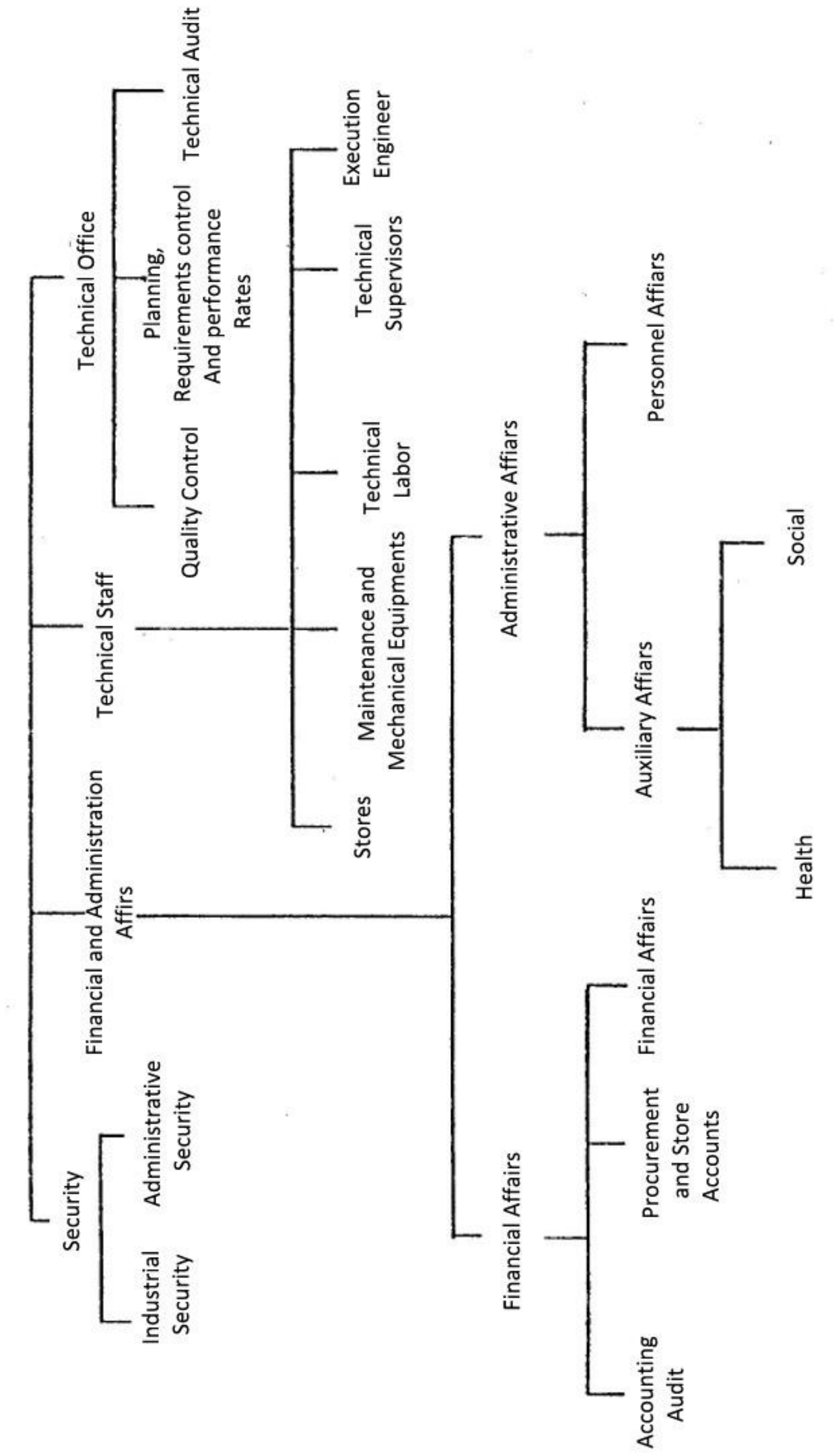
D. Revise the financial situation and stores stock.

E. Approve workers allowance on the light of the achieved works.

1-6-1 Technical Office:

The technical office has the main role in preparation of all technical, design, planning, follow up, requirements and performance rates data for execution and full completion of the project according to the approved schedule. Role of the technical office is summarized in the following:

Fit (3-4): Contractor Organizational Structure



1-6-1-1 Technical audit: It is responsible about the following:

A. Revise conditions, specifications and provisions dossiers.

B. Prepare and count all work items required to be executed in the project.

C. Revise bid documents, prepare and release tenders to subcontractors.

D. Prepare and revise the payments according to the actually executed quantities and compare them with the shop drawings and collection records before submission to project consultant.

E. Follow up execution of the project according to the time schedules.

F. Prepare closing payments and preliminary handover reports of the project.

G. Revise hydraulic drawings with the mechanical and electrical drawings and their conformity with the architectural and construction drawings with provision of copies of the shop drawings.

H. Revise soil research report and ensure that locations of the executed borings are in conformity with what shown in the drawings and shall perform soil researches, if required, at his expensive.

I. Prepare copies of as built drawings according to what actually executed for approval from the consultant.

1-6-1-2 Planning, control, requirements and performance rates:

It is responsible about the following:

1. Prepare the planning budget and identify the obstacles and problems, if any, to be solved in timely manner.

2. Prepare different time schedules, use systems, such as personal computer, to facilitate revising all the information required to execute different stages of the project, provide the necessary requirements as well as communication and continuous cooperation between the concerned parties to complete the project on time.
3. Determine the resources necessary for the project, provide the materials and equipments according to the specifications with the necessary quantities on suitable times to execute the project in accordance with the specified time schedule.
4. Follow up execution of the project, action plan and all execution steps through the time schedules and performance rates and amend their course in case of any delay in execution of the project.
5. Follow up collection of financial claims.

1-6-1-3 Quality Control:

Perform inspection and test works on the materials and revise manufacturing works to ensure that they are in conformity with contract documents.

1-6-2 Technical Staff:

1-6-2-1 Execution Engineers:

Execution engineers, with the required engineering specializations, shall perform accurate technical direction and revise the quality according to contract documents.

Duties of execution engineer are summarized in the following:

A. Takeover, plan, determine axes and directions of the site.
B. Prepare the necessary detailed sketches that help in execution of the project.

C. Demand the equipments, materials, labor and supplies on suitable times according to time schedules.

D. Direct technical supervisors and distribute labor according to work needs.

E. Execute all the works according to time schedules.

F. Prepare daily reports on work progress and the obstacles that face the execution and methods of their solution.

G. Periodic count of the executed works and payments.

H. Give directions for better use of the materials, equipments and instruments and their storage on the site.

I. Stores supervision.

J. Prepare as built drawings.

1-6-2-2 Technical Supervisors

Duties of the technical supervisors are summarized in the following:

A. Implement instructions of execution engineers

B. Control and direct technical labor.

C. Report the obstacles immediately.

D. Receive materials and equipments from the stores and settle the custody.

E. Maintain the equipments and execution tools and their proper use.

1-6-2-3 Technical Labor:

Technical labor shall carry out the works accurately according to the instructions issued from the execution engineers and supervisors.

1-6-2-4 Maintenance and Mechanical Equipments:

Duties of maintenance and mechanical equipments unit are summarized in the following:

A. Prepare, maintain and operate the equipments.

B. Perform periodic maintenance works for mechanical equipments.

C. Train the workers on maintenance and operation works.

1-6-2-5 Stores:

It performs the following duties:

A. Keep store records that show all the supplies, their dates of supply and values and the issued quantities.

B. Receive and store all the materials and equipments supplied to the project according to technical principals after completion of inspection and addition procedures.

C. Receive the materials and equipments necessary for the works.

D. Prepare item cards, their quantities and put them in clear places on the site.

E. Demands provision the stores with items that their stock reach to the critical limit.

1-6-3 Financial and Administrative Affairs Unit:

It consists from the following:

1-6-3-1 Administrative Affairs:

It consists from personnel affairs and auxiliary services.

1-6-3-1-1 Personnel Affairs:

It has the following duties:

A. Provide the necessary labor required for the work.

B. Prepare and follow up workers pay roll

C. Prepare production allowance lists according to work progress.

D. Prepare and equip the offices and rest rooms necessary for service of all workers in the project.

E. Prepare monthly and annual lists on technical and administrative competency of the workers.

F. Follow up attendance of workers

G. Follow up attendance of workers

H. Determine and follow up leaves according to instructions.

I. Prepare decisions on transfer and service termination of workers.

J. Perform Social insurance procedures

K. Issue work permits and complete security procedures, if necessary.

1-6-3-1-2 Auxiliary Services:

It includes social and health services.

A- Social Services:

It has the following duties:

- Supervise workers welfare fund, where all the workers of the project participate and get benefit from it in the cases that require this.
- Organize recreational, cultural, tourism and religious excursions and field visits to similar work sites.
- Organize different sport activities.

B- Health Services:

It has the following duties:

- Prepare health unit for first aids and treatment of injuries and quick cases.
- Transfer injured people with serious cases to the specialized hospitals.

1-6-3-2 Financial Affairs:

It consists from the following:

1-6-3-2-1 Financial Accounts:

It has the following role:

A- Revise the payments and follow up letters of credit.

B- Perform follow up works and collection from the employer.

C- Prepare record for accounts of suppliers, revenues and expenses

D- Prepare the budget and determine work results.

E- Supervise the purchases.

1-6-3-2-2 Procurements and Stores Accounting:

Role of procurements department is summarized in the following duties:

A- Purchase the materials and equipments, ensure their supply to the site on the suitable time and keep regular records in this regard.

B- Report any shortage of supply of the materials and equipments.

C- Calculate delay fines imposed on the suppliers.

Role of stores accounting is summarized in the following duties:

A- Revise the supplies, their prices and quantities according to the contract.

B- Revise notes payable submitted from any department with the approved forms and send them for auditing.

C- Keep a record of stores accounts for comparison with the inventory record.

1-6-3-2-3 Auditing:

Its role is summarized in the following:

A- Revise the payments with the count records and conform the rates to the contracts.

B- Revise project financial claims.

1-6-4 Security:

It consists from administrative security and industrial security.

1-6-4-1 Administrative Security:

Role of the administrative security is to monitor work sites, gates and guard works, including entrance and exit of personnel and equipments, prepare security arrangements to ensure proper and smooth progress of work and revise work permits.

1-6-4-2 Industrial Security:

Role of industrial security is to secure the project as follows:

A- Fire resistance, provision and maintenance of the necessary equipments.

B- Secure workers during the work against injuries and work risks.

2- Site planning and preparation:

Introduction:

The best way to reach the desired goal starts from good planning and analysis of project components to the executive steps prior to the implementation process which create the site to work, including handover of the site, survey the site, preparation, coordination and overall planning and layout of the site including temporary buildings that must be completed before starting implementation of the works so that the project contractor can do the main works easily.

These works are divided into three stages:-

A. Determination and handover the site, survey works and preparation of the studies.

B. Planning, coordination and preparation for the layout.

C. Temporary buildings works.

2-1 Determination and handover the site, survey works and preparation of the studies:

2-1-1 Determination and handover the site:

- Takeover the allocated area of the site from a committee consists of the owner, the consultant, the contractor, representative of the beneficiary body of the project and representative from survey department in the governorate by putting iron fence around the site by representative of survey department.
- Determine the obstacles that hinder execution of the works whether over or under the ground.
- Determine takeover situation of the site "one stage" or "several stages" and date of takeover of each stage.
- Determine water and electricity supplies around the site, if any.

2-1-2 Survey works and preparation of the studies:

- Current condition of the site is photographed before start implementation.
- Takeover the bench marks under takeover record signed from owner representative, the consultant and contractor representative after accurate revision of the levels, directions and site dimensions and compare them with the layout drawing to ensure from the correct dimensions.
- Construction of concrete blocks around the bench marks taking into consideration to be away from the excavation area to be hard to removed.
- Perform studies on quarry and workers near from the project to determine the best elements that can be used at least cost.
- The site is divided into net of squares to perform initial network level by preparing sectors of this level to determine excavation cubes, backfilling and leveling.
- Perform the main axes of the site away from the temporary buildings and internal roads of the site.
- Prepare a drawing includes all the obstacles on the site.
- Removal of all obstacles on the site that hinder the implementation process, such as wastes, trees, old buildings, etc.
- Perform the necessary leveling for the site, including excavation and backfilling according to site conditions taking into consideration the proposed implementation methods, project execution level, weather conditions, rain flow directions, etc.
- Perform coordination records with the different bodies before start implementation and the necessary diversions, if required.

- Perform additional soil borings, if necessary according to contract terms.
- Perform geological study to determine the faults and storm water drains.
- Fencing the site and construct a gate for entry and exit of equipments, as well as the Security Office.
- Supply the site with water, electricity, sanitary drainage, communication, etc.
- Perform network level again after leveling and reaching to the design level.
- Study situation of the adjacent buildings and their effect on excavation processes to avoid any cracks and submit report in this regard to the owner to take the necessary actions.
- Issuance of the necessary permits and licenses.
- Select the best places to put project sign in coordination with owner representative and the consultant.

2-2 Planning, coordination and preparation of the layout:

Success of any project is measured by allocation of sufficient time for planning and applies implementation methodology as follows:

2-2-1 Studies required for proper planning of the site:

The following studies are prepared by project consultant and must be used before start implementation:

- Site, contract terms, project shop drawings, proposed construction methods and plan for the required services.

- Specifications and details of the drawings of the required equipments.
- Time and technical schedules for the equipments, materials, labor, etc. to determine supply periods for project needs in order to decrease the areas used in the stores, losses and motionless items and implement the works on the specified dates.
- Construct concrete mixing station on the site according to implementation conditions.
- Details and requirements of the temporary buildings “Offices, accommodation, stores, workshops, etc”.
- The proposed alternatives in case that site area can not accommodate the temporary buildings, such as rent another lands or administrative units, etc.
- Requirements of industrial security and administrative security in site planning.

2-2-2 Elements to consider when studying perform proper planning for the site:

- Effect of wind direction on determination places for welding workshop, storage areas, office building, residential units, etc.
- Effect of rainfall direction, inclination of site land and methods of storage on the ground.
- Motion flow inside employee offices, stores, workshops, etc.
- Determine suitable places for car parking and allocate reception office for visitors.
- Planning of temporary internal roads to facilitate motion of equipments, individuals, raw materials, etc.

Temporary roads network on the site must be on the same route of the main roads network of the project and not intersect with project constructions.

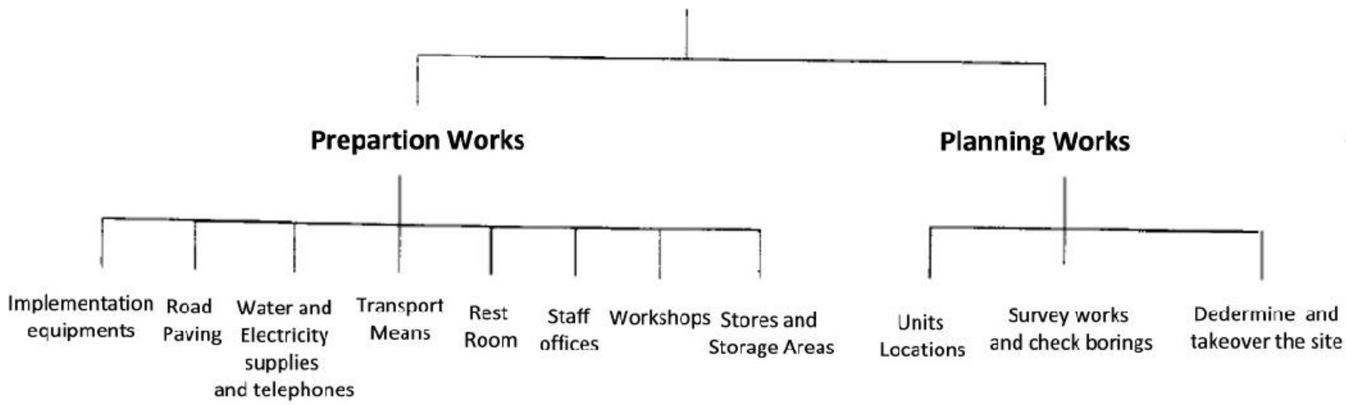
- Take measures to protect the adjacent constructions, such as using dewatering methods and digging piles, poles, etc.
- Provision of places and utilities lines on the site (water, electricity, sanitary, telephones, etc).
- Perform study to analyze well water on the site.
- Determine places for materials storage, including mixing stations and workshops to decrease losses and transport costs. Storage areas must be in places that do not hinder the work and communication inside the site and to avoid storage on excavation areas and reduce as much as possible relocation of stores throughout the project implementation period.
- Raw materials entry cycle for "check, classification and storage" and exit for implementation.
- Study size, motion and height of heavy and fixed equipments inside the site during construction process.
- Provide lighting, guarding, warning signs, banners, etc.
- Equip a laboratory for materials and concrete researches inside the site and fuel station for equipments according to the importance of the project.
- Provide signboards identifying locations of the project "administration offices, rest rooms, visitor's office, toilettes, unbalance unit, mosque, stores, workshops, working areas, etc".

2-3 Temporary buildings:

2-3-1 Factors affecting construction of the temporary buildings:

- Contract terms.
- Wideness of the layout.
- Type of the project.
- Implementation period and time schedule stages.
- Method of construction and type of the used equipments.
- Location of the project "remote or civilian area".

Fig (3-5): Site Planning and Preparation



3- Implementation of civil and architectural works for water purification plants

3-1 Introduction:-

The purpose of construction of water purification plants is to obtain pure water in conformity with health standards fit for drinking and human use.

Water purification plants consist from:-

- Intake and its components.
- Sedimentation, flocculation or clarification.
- Filtration
- Disinfection.
- Service buildings.

3-2 Conditions of implementation of civil and architectural works

When starting implementation, it must take into consideration all provisions of Egyptian Codes concerning reinforced concrete, soil mechanics, foundations and pipes.
It must take into consideration the following:

- Revise project documents and planning of unit locations.
- Determine ground level of the site from the nearest bench mark.
- Installation of the assisting supports in fixed and clear locations inside the site.
- Determine priorities of implementation according to foundation levels.
- Determine storage locations of the equipments used in implementation.
- Use of suitable formworks to obtain fair face concrete surface.
- Treatment of places of intersection of the local pullers or to use French pullers.
- Install of wall connections before pouring the reinforced concrete and the existence of the wall washer in the middle of the wall with diameter not less than 1.5 pipe diameter.
- Care of rounding concrete edges of heirs and their linearity and to adjust their levels

- Check inlet and outlet levels for all units.

- Follow up of the implementation program and instruct the contractor about any delay or any work not in conformity with the specifications to avoid delay and continue the work according to the implementation program.
- Final drawings of the general layout must be prepared according to as built drawings.

When implementing the filters, the following must be taken into consideration:-

A- When using filtration tiles provided with plastic nozzles: -

- Revise dimensions of the metal forms of filtration tiles after assembly and tying firmly.
- These forms must be easy mantled and dismantled.
- The forms must be cleaned well after each pouring and care of cleaning and washing of tying screws.
- Formation and tying of rebar of filtration tiles at the outside and then the cage is transferred inside the form.
- Locate the external body of filtration nozzles inside cage of rebar to be tied well before pouring.
- Revise dimensions between filtration nozzles before pouring reinforced concrete.
- Use the course aggregate in the reinforced concrete, and proportion of the cement in the mixture is not less than 400 kg cement / m^3.
- Remove the forms after pouring by 48 hours with absolute care.
- Tiles are moved by hands inside water treatment tanks prepared for this purpose and will be arranged carefully in lines and rows over each other and flood by water for a week at least.
- Tiles will be moved again by hands after treatment and placed inside filtration tanks by ropes or by suitable method that does not affect tiles safety.
- Damaged tiles are removed (uneven surface, broken edges, twisted).

- Before arranging the tiles inside filtration tanks revise the levels and adjust leveling of walls carrying the tiles and it is not allowed to place any thicknesses under the tiles.
- It is not allowed direct walking on filtration tiles after being arranged on the carrying walls.

B- When using pre-cast concrete filtration tiles with holes:-

- These tiles are poured in the site in the shape of a cone at the head and half perforated cylinder at the two sides or according to the shop drawings.
- Tiles are flooded with water inside special tanks for seven days at least.
- Tiles are arranged in regular rows inside filtration tanks over the surface prepared for installation and adjust leveling of the rows before installation on the ducts.
- Gaps between tiles are filled with cement mortar not less than 400 kg cement / m^3.
- It is not allowed for the workers to walk on the tiles after arranging and filling the tiles.
- Thickness of the different layers of the filtration medium must be determined by clear color according to the drawings.
- Lower layer of filtration medium is laid by hands without using any iron tools to not scratch the tiles and to revise the levels regularly to control thickness of the layers.

To keep the life span of water concrete constructions, they must be insulated as follows:

A. Internal insulation only if the construction is over groundwater level.

B. Internal and external insulation if the construction at the level of groundwater.

4- Implementation of mechanical and electrical works

4-1 General Conditions

When implementing mechanical and electrical works for treatment plants, the following elements must be taken into consideration:-

4-1-1 Before installation:

A. Revise the implemented civil works to ensure from the design dimensions according to the shop drawings, levels, inclinations and all civil finishing works as mentioned in the drawings and specifications of these works.

   Also, care must be taken to revise dimensions and axes of the holes and their levels and the necessary requirements to achieve them and install mechanical equipments through these holes according to shop drawings of mechanical works.

B. Supervise implementation of equipments according to the dimensions specified by the manufacturer according to catalogues and the approved drawings, and must take into consideration to use the materials according to instruction and to adjust level of the surfaces.

C. Clean tanks, channels and all civil units form any remaining construction and building works during implantation.

D. Revise quantity and quality of the mechanical equipments and compare them with the supply order in terms of model, serial number, country of origin, inspection certificates, test certificates and make sure of the components and parts of the mission and compare them with bill of quantities and mechanical detailed drawings.

E. Visual inspection of the equipments to check existence of breakage or damage occurred during transportation.

4-1-2 During installation:

A. Develop steps for equipments installation for each unit, taking into consideration to arrange installation of equipments with respect to each other, such that installation works for pumping equipments start first (cranes), then the equipments installed at the lower levels, then the upper one, and so on. Also, must follow instructions in suppliers and manufacturers manuals.

B. Must take into consideration to adjust axes levels of the equipment before pouring their bases and to implement the connections between equipments.

C. Must check correct installation of valves in terms of direction of open and close, their order and directions (arrow direction on the valve)

D. Check all parts required to be lubricated and to use oils and grease according to manufacturer instructions.

E. Must also check electrical connections between mechanical equipments and control boards.

F. Check adjustment of inlet and outlet levels of the units as well as adjust outlet heirs using right scale.

4-1-3 After installation:

- After completion of installation works and before start operation, each equipment must be operated for short time to insure direction of motion.
- Test experiments are performed on the site as indicated to tests section.
- Operation period for performance tests must be started without stop for at least 72 hours, in case of completion successfully without problems or obstacles, preliminary handover report shall be issued and then warrantee period is calculated for these equipments from this date.

4-2 Conditions of installation Mechanical and Electrical Equipments

4-2-1 Pumps

- Before installation of the pumps, must ensure at first, fitness of the pumps after shipment and transportation to the site and non-existence of breaks or cracks on the pump body or any defects in any part thereof.
- Must conform the data listed on the data tag of the pump to the data and specifications stipulated in the contract.
- It is necessary to obtain full information about correct installation of the pump, including all details of the pipes, corresponding water levels, maximum and minimum operating conditions from pump manufacturer manual. Pump base must be implemented according to instructions of the manufacturer and if it is necessary to make a layer (structure) of steel sections, the measurements must be adjusted and keep a degree of levelness and take into consideration level of the concrete base on which the steel structure will be installed.
- Must give great care for alignment of the axes to reduce periodic maintenance works for the glands, and by using flexible coupling, effects of misalignment can be avoided.
- In all cases, must follow manufacturer instructions when align the axes to avoid usage of axes bearings which have rapid corrosion and damage.
- Pump must not be used as a tool for fixing the pipes and care must be taken when installing pipes and valves system for the pumping station and ensure that there are no strains transferred to pump nozzles (due to misalignment) which causes clutching of the pump or breakage of the parts made from castings.

- Position of the pump (mounting level) with respect to the suction water level must be taking into consideration and existence of separate suction pipes for each pump in case of multi-pump stations.
- If it is necessary to execute common suction line for the pumps, must take into account that maximum hydraulic inclination of the suction pipes occurs at maximum operating conditions and not to decrease the pressure in the common suction pipe at any point less than the value at which the pump is at the standby position under suction pressure less than the atmospheric pressure and leads to be escaped through the glands and the pump becomes air locked and unfit for operation where it needs reset.
- Must take into account the allowed percentage of suction pipe reducers.
- Suction pipes must be put inside the sump and ensure that their levels are in accordance with the design, as uncover of the suction nozzle with appropriate minimum level leads to formation of air bubbles enclosed inside the pump and causes lose of priming while the pump is running.
- Must avoid existence of high suction pressure on the pump whether by changing its mounting level or using high friction pipes or existence of blockage at the suction side whether at the suction inlet or existence of gate valve not completely open and leads to confinement in the pump and cause wearing for pump metal surface due to formation of steam sinuses inside the liquid and accumulate on the solid surfaces of the pumps.

4-2-2 Electrical Motor

- Before installation, must inspect the motors and make sure that they are not damaged due to improper storage for long periods.

- Motor must be clear of any symptoms of corrosion before installation.
- Resistance of motor windings must be measured by megger device to ensure that they are not affected by humidity during storage. The resistance must not less than 1 Mega, and if it is less than this value, the winding must be dried and re-measured again.
- Ratings of the motor must be checked and compared with the data tag and supply documents.
- Must make sure that the place of motors installation is safe and is not subject to fire, risks or corrosion conditions except if the motors are designed to operate in these conditions.
- Must remove any dust or deposits on motors parts before installation and check fulcrums, connection points and slip rings to ensure their fitness and not being subject to corrosion or cracks.
- Must check motors bearings grease (except the sealed types and those designed to work over life span of the equipments) and ensure their fitness or replace it if necessary.
- Motors must be mounted on solid and flat base to avoid vibrations. Usually, the base consists of a bedding from steel sections mounted on reinforced concrete sill taking into account to be the tying screws carefully commensurate and to assemble the bedding such that the surface is flat and their axes are aligned when putting on the concrete sill and sealing of the bedding after leveling and alignment.
- If the cost of the bedding is high, the motor can be mounted directly on the concrete base using wedges inserted in the concrete, usually from cast iron with smooth top and longitudinal reduced hole and cracks on the body to ensure good cohesion with the concrete. Wedges are tied with motor legs and the motor is mounted on the concrete base for proper adjustment. Permanent mortar cement is used for sealing. After final adjustment and leveling, holes are punched in opposite direction of motor leg inside base wedges and insertion of pins to facilitate re-installation works of the motor on the base.

- Simple adjustment, height adjustment or motor replacement can be achieved by using shims under motor legs.

  Doweling is also used after sealing (alignment) and final adjustment of the motor in case of using steel bedding.

- Large motors with axes mounted on a manufactured base usually have bedding with lower structure from cast iron to be mounted directly on the reinforced concrete bases prepared for this purpose.

- Motors with flanges or vertical motors are installed usually on lower structure. Vertical motors are mounted on pre cast skirts especially for driving the pumps and are considered motor stool.

4-2-2-1 Alignment

- Fine adjustment is the main requirement to avoid faults of bearings and couplings. Alignment is performed between the motor and the pump before tying the joints.

- Faces of the joints must be in parallel and to take into account any spacing between the faces recommended in manufacturer instructions.

- Alignment is finally performed for the joints and revised using pointer meter.

- Double bearing motors are connected with the pump by flexible joint to decrease transfer of shock loading to bearing.

- Single bearing motors are connected with the pump by using solidly bolted joint and not flexible joint because these motors are not designed to withstand downward thrust resulted from rotor weight.

- Mechanical mounting of the motor is completed when the two halves of the joint are connected. It is required more inspection before supply the electrical current and to make sure that the motor cooling air is flowing without obstacles whether from the air inlets or exhaust outlets, as the insufficient space between air inlets and the adjacent walls leads to temperature increase.

- Must ensure that all covers are removed and any gates must be kept open during motor operation.

- All auxiliary equipments must be checked and properly fixed, such as air compressors, rpm meter, external coolers, filters, bearing vibrations or temperature probes and bearing oil circulation equipments.

- Must test cross section areas of motors power and control cables and conductors according to the design and to check and compare the operating voltage with the design.

- Must check cable terminals to ensure that they are properly connected for good conduction of electricity.

- Must connect earth screws carefully with the motors according to instruction of the competent bodies, applicable regulations and manufacturer proposals.

- Must adhere with safety rules, fire and explosion risks prevention.

4-2-2-2 Start Motion:

- After installation of motors and proper connection of their cables, addition check is performed to insure that the bearing is good greased, efficient operation of the cooling system, air inlet and outlet without any obstacles and the electrical current is connected to all ventilation fans with separate drive to ensure they are rotating in the correct direction.

- Must ensure that motor cooling fan is rotating in the correct direction according to the specification illustrated in the connection circuit with respect to motor rotation as indicated in motor data tag or on motor body.

- After initial check of the motor after installation, operation and loading of the motor, the necessary inspection must be performed to ensure from vibration rate, monitor and control reading of speed and measuring meter.

4-2-3 Motor Control Center (MCC)

- Before start installation works, must revise manufacturer drawings and compare them with contract drawings.

- Must inspect location of installation of MCC and its relation to cable trenches and paths.

- Must carefully plan for future cables installation before installation of MCC.

- If MCC is of floor mounted type, must provide with flat base.

- Must take into account total height of MCC and compare it with building height and upper cable trays.

- Must take into account ventilation of MCC in order that MCC is working in low temperature and decrease vapor condensation inside it.

- For performing preventive and periodic maintenance and to facilitate troubleshooting, must take into account easy access to MCC when putting the equipments.

- MCC must be installed in places with low vibrations and to be fixed vertically and firmly in order not to affect MCC components. Screws, nuts and terminals must by firmly tied before operation of MCC. Before connection of the motor with the control panel and starter motion, must ensure their capacity according to data tag for each of them.

- Cable terminals (power and control) connected and going out from the MCC must be marked according to the numbers indicated in the detailed drawing of MCC to facilitate and ensure correct connection.

- Cable paths must be kept away from any hot parts or bodies such as heater grids and resistance block, and if it is difficult to avoid this, must use heat resistant cables.

- Must be cared not to scratch the cables by sharp tools such as iron tools, screws, etc.

- When laying the cables, must adhere with the specified number according to design drawings to prevent over heat that affects cables efficiency.

- Must put marking, warning and safety tags and different covers after installation.

- Must earth all parts of MCC.

- Before connection of the electrical current, must take the necessary steps:

- Perform insulation resistance test for all terminals and distribution bars and to isolate or disconnect measuring and control devices before apply the high tension.

- Operate all the magnetic devices manually to ensure that all the moving parts are working freely.

- Revise electrical connection terminals to ensure correct and safe operation.

- Disconnect the temporary connections that required for transport of the boards (or any fittings) for the bridge connected on current transformers.

- Revise ratings of the relays on the actual loads of the MCC according to data of the working motors connected on MCC.

- Revise operating times for the timing devices.

- Clean all internal parts of MCC.

- Test operation of all control and safety (protection) circuits.

4-2-4 Transformers:

- Before installation, transformers must be checked to ensure that there is no fault or breakage resulted from transportation. For oil transformers, must check oil level and any leakage.

- Must check painting of the transformers and note any defects.

- Must check transformer terminals and note any mechanical defects.

- Must check the connections and windings and note any defects in the insulation.

- Must carefully check resin of the dry transformers, as it is easy to be scratched or cracked and ensure there fitness before installation.

- For oil transformers, must provide passes for the leaking oil for collection of the leaking oil taking into consideration possibility of occurrence cracks or holes affecting main tank of the transformer.

- Shape, size and type of the materials used in construction of the transformer enclosure are determined according to rate of disposal from the heat resulted from the fire of transformer oil.

- All types of dry transformers must be installed inside the buildings and surrounded by metal frame connected with the earth (or metal grid barrier).

4-2-5 Distribution Panels:

- Before installation, must ensure existence of the drawings and instructions issued from the manufacturer of these panels that give directions for installation.
- Must ensure that the chamber in which the boards will be installed is clean and dry and to remove any existing wastes.

- Must close and cover any unused cell in the board that may left for emergency.

- Must keep all insulations in the board clean and dry and cover them during installation works.

- Must use the correct method of handling and mounting must be on the points specified by the manufacturer in order not to subject any parts of the board to stresses or sudden load that may lead to damage or defects to board body or its components.

- Proper installation of the boards and safety of operation depend to a great extend on accurate implementation of the bases of the boards.

- The best method for implementation if distribution boards bases are the steel sections shaped in the form of channel buried under the ground below the boards and provided with screws (bolts) and nuts and must take into consideration that these sections are parallel and leveled and little jut out over the level of the floor surrounding the boards.

- The board is installed on the base by direct mounting on the steel structure of the base after being leveled.

- Base steel structure can be replaced by bolts put inside pits prepared during pouring of the board's chamber flooring and the bolts are put inside it and then perform sealing around them and then the boards are installed and fixed by these bolts and their suitable nuts.

- If the switchboards are supplied in parts to be assembled at the site, middle parts are installed first then the sides to ensure non-accumulation of mistakes that can not be noted in case of non-matching between the different parts of the board. Water pipe is used to ensure alignment of the board parts during assembly, taking into account to leave the screws between the parts untied until completion of parts assembly.

- After installation of the board, must check and ensure that all the movable components of the board can be easy removed and also easy open and close of the doors and covers of the board cells.

- Devices and components supplied disassembled must be inserted in their specified places to be maintained during transportation and then connected after installation and mounting of the board.

- When connecting the cables to and from the board, must avoid any severe bending or squeezing of the cable. Cable terminals must be installed in a way that not allow for any stresses or excess tension on the cable terminals after connection, taking into consideration maximum diameters of bending for these cables according to the measurements determined in the standard specifications.

- Earth of each board must be connected to all metal parts in the boards, enclosures of the measuring instruments and earth points of the switches through tying or riveting and never by welding. Earth wire must be continuous and fixed firmly with the main earth through tying or riveting also.

5- Tests

All materials and equipments used in construction of the pumping stations are subject to tests necessary to ensure their fitness for use and their required purposes.

These tests are divided into two parts, one is performed inside production facilities and the other is performed in implementation sites.

The following are types of materials and equipments required to be tested inside production facilities and implementation sites.

5-1 Materials

They include sand (small aggregate), pebble (large aggregate), cement, mixing water, pipes and fittings, lime, gypsum, insulating materials, stones, tiles, marbles, granite, painting materials, chemicals, asbestos, wood and glue, glass, iron sections, aluminum sections, welding materials, screws and accessories, laid grids and wires, construction partitions, ceramics and faience, rubber products, vinyl flooring, cork, metal and non-metal plats, steel sections, hoses, paving materials and metal products and their alloys.

5-2 Architectural accessories

They include hinges, lockers, handles, latches, faucets and valves.

To test the materials and equipments inside the factory or in the places of extraction, the owner or his representative shall monitor the manufacture process, if necessary, whether at the workshops of the contractor, factory or quarrying from which the contractor obtain these materials, and he has the right to enter and remain in these places during manufacture or extraction of these materials.

5-3 Equipments

They include motors, pumps, generators, cables, distribution and control boards, valves, cranes, measuring and alarm devices, gates, transformers, conveyors, screens, protection devices, tools, control devices, workshop instruments and fire fighting equipments.

These tests are performed at the expense of the contractor to ensure that each part of these equipments is manufactured according to Egyptian standard specifications for the equipments manufactured in Egypt, and according to terms and conditions of the contract. For the equipments imported from abroad, the engineer or his representative shall present at manufacturing facilities for accurate inspection. The contractor shall notify the owner by the names of the factories, workshops and suppliers from which shall obtain these materials before start in the works trusted to him. The contractor shall submit certificates from the approved inspection committee for the imported equipments from abroad and it is not allowed shipment of any equipments or supplies without being inspected by owner representatives.

The contractor shall provide the owner with copy of the drawings and specifications approved for this purpose and the owner is authorized to test theses equipments and supplies which will be supplied by the contractor according to contract conditions. The owner is entitled to reject any equipment that are not in conformity with the specifications and shall approve the inspected samples and put discriminated mark to prove that they are passed the tests successfully and on the basis of them the equipments will be supplied to the site.

5-3-1 Equipments test at production facilities

- These tests are performed for all equipments that are contracted to be supplied before transportation from the contractor or producer factories.

- Different equipments shall be installed and operated (to the most possible extend) according to actual operation conditions at the work site.

- Mechanical equipments that are driven by electrical motors must be tested on the same motors except if the operating voltage of these motors is not available in the production factories or contractor test laboratories. In this case, tests can be performed on typical motors and the available calibration for such tests taking into account to calculate the actual consumed powers to ensure operation of the equipments when being driven by their motors at work site with the same efficiency and accuracy.

- The above item is applied in case of different measuring instruments that must be used to calculate the measurements of the mechanical equipments which shall be supplied for the project, if possible.

- The measuring instruments used in performing the tests in production facilities must be calibrated and to check the supporting certificates from the certified bodies in the manufacturing country, taking into consideration ratings accuracy and compare it with the accuracy indicated on the data tag from the producer.

5-3-1-1 Hydraulic Pressure Tests

All castings, valves, pipes, special pieces and any other pieces in the equipments subject to pressure must be tested under a pressure equal to double maximum pressure designed for the work.

5-3-1-2 Tests of materials and apparatuses

All materials used in the manufacture and any apparatuses necessary for the equipments must be tested according standard specifications of the producing country or to international standard specifications ISO and to obtain approved certificates from the competent bodies.

5-3-1-2-1 Mechanical Screens

A- Design Documents

- Revision and approval of execution documents.

B- Steel manufactures

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Inspection of surface treatment against external effects.

C- Assembled parts (materials and components)

- Visual inspection of the assembled parts and their dimensions.
- Electrical and mechanical test (try installation at the workshop).

D- Electrical motor and gearbox

- Revision of conformity certificate.
- Inspection of dimensions and paintings
- Running test.

E- Before shipment

- Final visual inspection and revision of markings and ensure fitness of equipments sealing.
- Revision of final dossier.

5-3-1-2-2 Removal of sludge , crawler bridges)

a- Design documents

- Revision and approval of the documents.

B- Steel manufactures

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.

- Visual inspection of the manufacturers and their dimensions
- Inspection of surface treatment against external effects.

C- Assembled parts (materials and components)

- Visual inspection of the assembled parts and their dimensions.
- Revise performance at no load (electrical and mechanical parts, operation, adjustment and control)

D- Electrical Motor and gearbox

- Revision of conformity certificate

E- Before shipment

- Final visual inspection and revision of markings and ensure fitness of equipments sealing.
- Revision of final dossier

5-3-1-2-3 Flocculation Tanks

A- Deign documents revision

B- Steel manufactures

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Inspection of surface treatment against external effects.

C- Ass. Drive Head

- Visual inspection and dimensions revision.

- Perform drive test

D- Assembled parts

- Visual inspection and dimensions revision
- Installation of parts in the workshop

E- Electrical Motor and gearbox

- Revision of conformity certificate

F- Before shipment

- Final visual inspection and revision of markings and ensure fitness of equipments sealing.

5-3-1-2-4 Chlorine equipments

A- Cylinders and containers

- Revision of manufacturing materials for bodies and nozzles.
- Visual inspection of welding and detection by rays.
- Revision hydraulic and air pressure tests.

B- Chlorinators

- Revision of manufactured materials certificates

C- Measuring and control devices

- Revision of manufactured materials and calibration certificates

D- Leak detector

- Revision of manufacturer certificates.

E- Pumps and fans

- Revision of conformity certificates

F- Before shipment

- Visual inspection of painting
- Visual inspection of all parts and their dimensions
- Final visual inspection and revision of markings and ensure fitness of equipments sealing
- Revision of test reports.

5-3-1-2-5 Penstocks

A- Revision of execution documents.

B- Revision of the materials for (gates, frame, shaft and seating)

- Reviewing materials certificate.

C- Installation

- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Visual inspection and dimensions
- Inspection of surface treatment.

D- Assembled Parts

- Visual inspection of the assembled parts and revision of their dimensions.
- Performance verification.

E- Before shipment

- Final visual inspection and revision of markings and ensure fitness of equipments sealing.
- Revision of final dossier.

5-3-1-2-6 Electrical Motor Test

Motors are inspected according to the following particulars and properties:

- Implementation.
- Manufacturing and finishing
- Main dimensions.
- Air gap measurement
- Paintings
- Correctness of documents.

These particulars are compared with specifications, drawings, accepted bid, codes and standard specifications.

The following routine tests are performed for the motors:

- Measurement of windings cold resistance.
- Measurement of cold insulation resistance (megger test)
- Measurement of detectors cold resistance (if any)
- Measurement of open circuit voltage of the rotor.
- No load properties.
- Closed circuit properties
- High voltage test (Dielectric test)

High voltage test is performed according to the voltage specified in the standard specifications for both stator and rotor.

The following performance tests are performed for the motors:

- Hot drive test.

- Load and efficiency properties.
- Over current test.
- Break down torque.
- Warm insulation resistance test (by megger).
- Pulse test for stator windings voltage.
- Inspection of radio interference.
- Inspection of vibrations and noise level.
- Measurement of motor resistance.
- Measurement of GD.
- Mechanical test.

Motor withstands over current for 15 seconds at least without sudden change in speed (under credit torque increase) at maximum torque of at least 60% over this corresponding to full load rating.

- The following inspection and tests are performed for rotor starter at the factory:
- Same inspection items as mentioned in the motors.
- All starters are subject to performance and high voltage tests.

5-3-1-2-7 Tests of electrical distribution boards (assembled)

- Inspection is performed for the following:
- Acceptance test for manufacturing and assembly.
- Revision of dimensions.

- Paintings.
- Revision of connections and wires.
- Correctness of documents.

These items are compared with specifications, drawings, accepted bid, workshop drawings, codes and standard specifications.

- The following tests are performed for the boards:
- High voltage test.
- Performance safety for the following:
- Operation- Control and protection circuits.

5-3-1-2-8 Generators

A- Preliminary inspection

- Revision of motor test certificate.
- Revision of generator test certificate.
- Revision of electrical control devices test certificate.

B- Group trial test

- Visual inspection and dimensions.
- Load test.
- Over load test.
- Speed regulation test.
- Voltage regulation test.

- Inspection of functional parameters.
- Inspection of clutched starter and components.

C- Before shipment

- Final visual inspection and revision of markings and ensure fitness of equipments sealing.
- Revision of final dossier.

5-3-1-2-9 Pumps

- Revision of routine test certificates
- Performance test

(Flow- head- speed- motor power analysis- efficiency- functional diagram- vibration- materials- paintings and surface treatment)

- Visual inspection and dimensions.
- Inspection of indicators panel.
- Inspection of documents and sealing.

5-3-2 Equipments tests at site

5-3-2-1 Water constructions impermeable test

Water constructions are tested to know there resistance to water permeability before being insulated by filing them by water to the specified height. The test is acceptable if there is no infiltration on the external surfaces and to observe the dryness of the tanks for seven days, then observed again for another seven days. At the end of second week, if there is no water leakage and the water level did not decrease more than 3 mm during the last 24 hours, the test is acceptable.

When measuring the level, must take into consideration losses by evaporation which must be measured by approved devices.

If conditions of test are not fulfilled, test period shall be extended to another seven days. The test is acceptable if the conditions are fulfilled.

In case of water leakage, it shall be immediately treated using sealing compounds with the approved methods.

5-3-2-2 Hydraulic Test:

Treatment units are tested at the site from beginning of water entering until coming out to disposal places to ensure from hydraulic levels during operation of mechanical and electrical equipments of all plant units.

5-3-2-3 Mechanical equipments test:

Tests at sit are performed for all mechanical and electrical equipments installed in pumping stations to ensure fitness of the supplied equipments and supplies to perform their function by performing the following tests at site.

5-4 Tests at site

5-4-1 Electrical Motors

Reliability test is performed for the motors at site by driving the motor at full load for 10 days and any changes or adjustment are not allowed during the test.

Motors must be rotated freely without existence of any vibrations and the temperature of each part of the motor must be within the specified limits according to original design of the motor.

5-4-2 Electrical Switchgears

5-4-2-1 Check list

- Manufacturer name:

- Production serial number:
- Operating voltage:
- Type of the switchgear:
- Components of the switchgear:

(Number of cells)

(Number of circuit breakers)

(Measuring instruments)

(Relays)

- External condition of the switchgear:
- Result of visual inspection:
- External equipments

- Cells lighting
- Motion of levers and switches
- Condition of doors and their hinges and locks.
- Interlock and interconnection between cells.
- Measuring instruments and glass covers.
- Earth connections.
- Mounting of bus bars and space between them.
- Heating elements.
- Terminals and their markings
- Safety instructions.

- Motion of switches and movable devices and ensure their fitness and greasing.

5-4-2-2 Measurements

- Measurement of electrical insulators resistance.
- Measurement of cables resistance by megger.
- Measurement of bus bars by megger
- Measurement of earth network resistance.

5-4-2-3 Inspection of the following:

- Cables and bus bars.
- Earthing equipments.
- Measuring and protection devices.
- Fittings of bus bars.
- Voltage and current transformers.
- Marking of the electrical circuits
- Cleaning of cells and devices.
- Motion of switches and relays.

5-4-2-4 Equipment Tests

5-4-2-4-1 High Voltage Test for Switchgear

Work tests

- CB must operate at the normal operating condition using the manual switch then the automatic control to simulate the control devices from outside the equipments.
- Current and voltage circuits must be tested to ensure correctness of the transformation ratio and poles for connection with the devices connected to these circuits.

- Ensure operation and accuracy of each device using approved devices with valid calibration.
- One relay is only tested to ensure accuracy and calibration using calibrated and valid devices.

5-4-2-4-2 Transformers Test

The following tests are performed for the transformers:

- Measurement resistance of all windings at the rating load and maximum position of tapping.
- Ratio test for all tapping positions.
- Poles and phase relation test
- Load loss at the rating voltage and impedance voltage.
- Induction current at rating voltage.
- Voltage test

- When testing winding insulation, induction voltage is tested over the nominal voltage at increased frequency.

Additional Tests:

- Pulse voltage
- Noise level
- Temperature rise
- Insulation test at high voltage for cables and bus bars.
- Twisting test on the bus bars.
- Test ON and OFF of switches.
- Test of relays controls and prove the accuracy.
- Test energizing of the relays.

- Test of indicators and warning lamps of the measuring instruments.

5-4-3 Electrical Cables

After installation and laying the cables, the following tests are performed:

A- Conductor continuity for the full length.

B- Start and end of the connections according to the approved drawings.

C- No short circuit between any phase conductors inside the same cable or between the conductors of the adjacent cables inside the same duct.

D- Value if the insulation resistance between the conductor and the earth or between the conductors inside the same circuit must tends to infinity.

E- Order of the phases when connected to the motors must be in the positions that ensure correct direction of rotation.

5-4-4 Pumps

The following operation tests are performed for the pumps after installation to ensure correctness of installation according to implementation conditions for a period not less than 24 hours of continuous operation.

5-4-4-1 Pumps installed on dry well

At the end of the specified operation period, must ensure that the pumps have passed the tests satisfactory without any problems and to measure the following parameters and compare them with warrantee tables for these pumps:

- Consumed power at different operating points over the approved operation range.

- No existence of any wears on the impeller or pump shaft.

- No existence of any vibrations or abnormal sounds at any operation point including stop point of the pump.

- Measurement of bearing temperature for the pumps and connection shafts and compare them with the standard values shown in the supplier catalog and the approved technical data of the pumps.

Suitable measuring instruments are used to record these readings. The measured vibrations (peak to peak) at any point of the equipment must not exceed 0.10 mm.

5-4-4-2 Vertical Turbine Pumps

The same tests of dry well are performed and compared with guarantee tables in terms of consumed power and efficiency, non-existence of vibrations or abnormal sounds and to measure temperature of upper bearings of the pump.

5-4-4-3 Submersible Pumps

For this type of pumps, operation test is performed twice, the first in air (without submersion in water) and the second after submersion. In the first case, water level inside the sump is kept under pump motor level. In the second case, the water level covers the motor completely during the operation period.

The following parameters are measured and compared with warrantee values for the pumps according to the contract:

- Motor temperature increase.

- Electrical power inlet to the pump and measured on the control board.
- No existence of vibrations or abnormal sounds during operation period and over pump operation period including stop point and to use the necessary devices for record.

5-4-5 Mechanical Screens

After installation and adjustment of screens according to implementation conditions, tests at site are performed to ensure that the entire screen as a mechanical system, including means of protection, is designed to withstand the subjected torque and the protection means are worked to avoid any faults for the screens due to load that exceeds the rating power of the electrical motor and driving unit.

5-4-6 Treatment unit's equipments

All treatment units' equipments must be operated continuously for 3 days and observe the following:

- No existence of vibrations or abnormal sounds at any part of the equipment and must be recorded by suitable measuring instruments. Vibration displacement must not exceed 0.10 mm at any part of the equipment (peak to peak)
- Calculation of rotational speed and linear speed of the equipments and compare them with warrantee values in the contract.
- Apply overload on the equipments and ensure that all protection devices are working efficiently according to warrantee values.
- Measuring the temperature at all bearings and compare it with the values in the operation catalogs and manufacturer data.
- Measuring the deflection in the meal bridges and compare in with warrantee values.
- Observe and measure outlet heir levels.

- Check existence of any corrosion or wear at any part of the equipment in contact with concrete constructions of the treatment units.
- Check operation of limit switches, reverse motion and fitness of overload protection devices.

6- Performance and handover Tests

Introduction:

Performance and handover tests of pumping stations are divided into two main parts:

6-1 Equipments performance tests

Performance tests are performed for all mechanical and electrical equipments supplied and forming the units of the pumping station at start of operation of the equipments and before their permanent operation to ensure their correct performance, accuracy and conformity with warrantee values as well as their reliability for continuous operation of the plant before start preliminary handover of the plant.

Period of performance test is determined by not less than 10 days of continuous operation of the plant provided that operation period of each unit does not less than 24 hours of continuous operation then the necessary measurements are performed.

6-2 Preliminary handover tests

Preliminary handover tests are performed to the pumping stage to ensure performance of its function as designed which is pumping of the liquid wastes through the discharge line to the final drain.

A General Conditions

- All mechanical and electrical equipments supplied and installed in different units of the plant are inspected and compared with contract requirements and ensure their installation with all accessories according to the shop drawings, tender conditions and specifications and the contract made with supplies and installations contractor.
- Make as built drawings including any amendments by decrease or increase according to instructions of the consultant or owner representative and approved from project consultant.
- Ensure handover of the spare parts supplied for each equipment by a detailed list and fitness of these spare parts and their storage according to technical principals.
- Submit O&M manuals for the units.

B Electrical tests before operation and connection of the current supply

- Insulation tests by megger

- Measuring cables insulation and contents of distribution board according to standard values.

- High Voltage Test

- All electrical equipments (motors, cables and distribution board components) are tested by calibration device transferred to the site. The test is performed by a voltage according to the standard specifications and not less than 1000 volt and measurement of the leakage current and verifies the standard result at site and their conformity with standard conditions, specifications and allowed limits.

- Control circuits tests

- Inspection of all control circuits to verify their efficiency according to tender conditions and specifications of the project.

- Distribution board protection devices test

Protection devices installed on the distribution boards are tested according to following:

- Short circuit
- Voltage increase and decrease
- Missing of any phase
- Direction change.

In addition to any other protection tests mentioned in tender specifications such as suction level decrease for the pumps and any other details.

- Earth resistance measurement

Earth resistance is measured by calibrated ohm meter. Earth resistance must not exceed 2 ohm/m except otherwise mentioned in tender specifications.

C- Tests after connecting electrical current supply

- No load test

Flexible joint between the motor and the equipment is removed and the motor is operated at no load for 3 continuous hours and measure no load current, motor vibrations, temperature and rectification time.

- Full load test

Flexible joint between the motor and the equipment is connected and perform alignment.

The motor is operated at full load for at least 24 hours / pump and measure the following:

- Rectification time by using timer.
- Test of over load protection devise and adjust it for full load. (motor rated power)
- Test of short circuit device and adjust it on 10 times motor nominal current.
- Measure of motor temperature over operation period for 24 hours.
- Measure of power factor using power factor meter.
- Measure vibrations of both motor and equipment.
- Calculate the difference value between motor power and maximum power of the equipment (service factor) and compare it with tender specifications.

- Measure and calculate total efficiency of the unit as well as electrical current consumption rate and compare them with design rates according to tender specifications

D- Pumps test

Flow and head are measured at the following points:

A- Operation when closing discharge valve fully and measure the head at zero flow of the pumps for only one stage.

B- Operation at duty point through control of the discharge valve and the flow is determined at this head.

C- Operation at maximum open of the discharge valve such that the value does not exceed motor rated current and adjust maximum control of discharge valve open at this limit.

6-2 Preliminary handover tests for plant units

A- Sedimentation tanks (Clarifiers)

Tanks must be operated continuously for 10 days at lease and measure the following:

- Sedimentation (Clarification) efficiency
- Removal 90% at least of turbidity and the suspended solids measured for the raw water coming to the tanks not more tan NTU.

- Removal 90% at least of algae measured for the same raw water provided that the number of algae is not more than 100 unit /m liter
- Calculation of sludge loss not more than 5% over the year.

B- Filters

Each filter must be operated for 10 days at least and measure the outlet flow and head loss within the filtration medium provide that to be 90% of the original flow.

Filtration Efficiency

- Removal of turbidity to be not more than 5 NTU
- Removal of algae to be not more than 10 units /m liter
- Loss percentage of filters washing must not exceed 2.5% over the year.

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Preparation of Egyptian Code Concerning Design Criteria and Rules of Potable Water and Sanitary Drainage Treatment Plants and Pumping Stations

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