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
Ministerial Decree No. 53/1998

Volume IV
Boosters
(Drinking Water)

2nd Edition 2006

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Minister Office

Ministerial Decree No. 53/1998
Concerning the Egyptian Code of Drinking Water Boosters Works

Minister of Housing, Utilities and Urban Communities

- 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 22/02/1998.

Decided the following:

Article (1): Part (4) of Egyptian Code Concerning Design Criteria and Rules of drinking water boosters works 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 and the amendments after their issuance are integral part of the code.

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

Minister of Housing, Utilities and Urban Communities
Prof. Dr. Eng. Mohamed Ibrahim Sulayman

Issued on 01/03/1998

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 sanitary drainage 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 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 sanitary drainage 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. 53/1998. Housing & Building Research Center shall publish, identify and train on this code for the development of drinking water implementation works in the Republic and the amendments after their issuance are integral part of the code.

With God's Blessings

Minister of Housing, Utilities and Urban Communities
Prof. Dr. Eng. Mohamed Ibrahim Sulayman

Introduction

Egypt witnessed throughout the ages civilizations as diverse as ancient Egyptian, Greek, Coptic and Islamic civilizations, where those interested in the areas of construction, which was clear in the houses of worship, palaces and temples.

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.

Chairman
Housing & Building National Research Center
Prof. Dr. Eng. Amr Ezzat Salama

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: Boosters.

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 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. Greater Cairo Water General Authority
3. Faculty of Engineering, Ain Shams University

4. Faculty of Engineering Zaqaziq University
5. Chamonix Consultation Office
6. El NASR Genera Contracting Company

Chairman of Standing Committee

Prof. Dr. Eng. Ibrahim Hilal El Hatab

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Chapter 1: Studies

Introduction

Boosters are used to compensate the pressure loss in the transmission pipe lines to supply the water to service areas, in addition to be used to increase the pressure in distribution networks, taking into consideration to achieve pressure balance during operation of these boosters.

1- Determination of service areas

Are the areas located at a level higher than pressure of the main water plant or the areas supplied with water at unsuitable pressures.

2- Determination of boosters' location

Location of the boosters is determined at the point where the pressure is lower than the permissible limit in the transmission lines, taking into consideration the following:

- Provision of the area required for construction of the booster and its components.
- Provision of the electrical power.
- Provision of the public roads to access to the site.

3- Types of Boosters

Boosters are divided according to the suction method to the following:

3-1 On-Line Booster

Booster is constructed adjacent to the transmission line with one of the following methods:

A- Pumps suction pipes are installed directly on the transmission line and the discharge pipe is installed on the same line, taking into account to separate the connection point of discharge line from the suction point.

B- Pumps suction pipes are connected directly of the transmission line and the discharge pipe is connected on another line.

C- Pumps suction pipes are installed directly on the transmission line and the discharge pipe in connected on other transmission lines.

2-3 Ground Tank Booster

Ground tank in constructed at the point of pressure decrease in the transmission line, where the water is sucked by one of the following methods:

- Through pumps suction pipe
- Construction of sump.

The booster is discharged in the transmission line with the same pressures or with less pressure in case of service the area around the booster.

Sterilization unit complete with its components will be added and operated in case of decrease of the remaining chlorine than the permissible limits.

4- Boosters general layout

After selection and determination of the location, booster general layout is prepared according to the main components determined by the hydraulic studies and survey works to include the areas necessary for booster components, taking into consideration the following when preparing the general layout:

1- Topography of the site, soil nature and groundwater level.

2- Connection of the site with the public roads.

3- Protection of the site from the external effects.

4- Construction of external fence around the site including observation towers, entrances, security rooms and information office.

5- Suitable distances must be kept between booster building and the other buildings to facilitated installation, operation and maintenance works.

6- Provision of store and workshop with suitable area for operation and maintenance works.

7- Provision of the administrative and services building away from pumps house which causing noise.

8- Distribution of the units in a way that allows future expansions.

9- Taking into consideration provision of alternative source of power supply in case of current interruption.

10- Suction and discharge lines must be away from sanitary drainage network and surplus of the tank.

11- Must take the suitable precautions to avoid risk of handling chemical materials inside the site.

12- Must decrease chemical lines to the least possible length to avoid operation problems.

13- Must provide the site with the necessary utilities, such as water and sanitary drainage supply networks, fire fighting, irrigation of the green areas, lighting of the site and communication.

14- Must take into consideration landscaping of booster layout and the suitable internal roads.

5- Means of Control and Protection

Control and protection means are the developed systems to control performance and efficiency of pumping station in terms of operation safety and achieve the health standards required for drinking water, protect it from pollution and ensure its management over the longevity of its different units.

5-1 Control means

The main purpose of using control system for the boosters, is to control and monitor operation of the different units to ensure optimum operation in the different conditions with the least possible expenses and to be sensitive to any hindering, stoppage or different path of the main operation processes. It also helps the operator to analyze and study the resulted data and enables him to improve operation methods and performance and save costs.

Boosters control system shall be determined to be manual, semi-automatic or automatic according to its easy operation and reliability.

Control elements in boosters operation depend on usage of devices and equipments whether mechanical such as the indicators or the actuators which depend in their operation of floats, rollers and connection levers, or hydraulic such as flow regulators and pressure regulators, or electrical (electronic) which are often used currently.

Control operation of different booster units is performed as followed:

1- Ground (reception tank)

- Manual gates are used to isolate parts of the tank in case of emergency or when performing periodic maintenance works.

- Floats and level indicators are used to control water quantities handled between units of production plant and pumping stations.

2- Suction collection pipe (when not using ground tank)

- Gate or butterfly valves are used for isolation works in emergency cases.
- Pressure indicators are used to control the quantities of the handled water.

3- For lifting pumps it is used:

- Level indicators for tank water or pressure indicators on the main suction pipe with warning devices or automatic disconnection of the pumps set when the levels are decreased than the danger limit.
- Level indicators for upper tank water or pressure indicators on the main suction pipe with warning devices or automatic disconnection of the pumps set when the levels are increased more than the maximum limit.
- Flow and pressure meters for control of water velocity and line pressure.

5-2 Protection means

The purpose of using systems and means of protection for the boosters is to protect and safe of all buildings and components of booster units, individuals and drinking water against all external effects and factors, and different operation conditions with continuous performance of work at the best possible efficiency. It is performed as follows:

5-2-1 Ground (reception) tank and upper tank

- Suitable isolation means for the tanks to protect the buildings and water from pollution risks.
- Overflow connections of water level increase for protection from drowning.

- Fences, handrails and covers to protect individuals and water against falling of pollutants.

5-2-2 For pumps and discharge pipes, it is used

- Non-return valves to protect the pumps and non-return of water at sudden stop of driving motors (current interruption)
- Protection devices against water hammering to protect pumps and pipes from bursting at sudden stop of pumps.
- Air relief valves at high levels of distribution pipes to protect them from bursting when forming big air bubbles at high velocity.

5-2-3 Motors and electrical equipments, it is used:

- Protection devices against short circuit, current increase or voltage drop.
- Warning means at different operating conditions.

5-2-4 Individuals

Provision of equipments, devices and means of personal protection for the workers in different fields of operation and maintenance, follow occupational health and safety instructions and provision of recovery and treatment means in emergency cases.

6- Survey Works

Survey works are from the important elements on the basis of which suitable places will be determined for the boosters and their components with the best use for save of the used power whether in terms of water quantities required to be pumped again, stored of transferred to another boosters or pump the water to the main distribution network for the consumers. Survey works are summarized in the following:

- Determination of north direction for each location.
- Longitudinal level works on the proposed line path distant at 50 m at most with the survey of the main landmarks along and at the sides of the path referred to the nearest bench mark.
- Network level works for booster location and its components distant according to nature of the ground and ranges from 5 to 10 m in the two directions referred to the nearest bench mark.
- Determination of fixed points with known level along the path and inside the site at suitable places and to be marked to refer to it.

7- Soil Studies

- Study of general layout of booster units to determine places and depth of the borings.
- Study of the hydraulic sector of booster units to determine depth of the required borings according to depth and loads of the constructions.
- When performing borings for sump location, must determine the suitable number and depth.

Chapter 1: Design Criteria

1- Hydraulic Design
2- Mechanical Design
3- Electrical Works Design
4- Architectural and Construction Design
5- Preparation of Tender Documents

1- Hydraulic Design

1-1 Booster Location

To determine booster location, must perform the following studies:

1. Draw the longitudinal level of the transmission pipes line path from the purification plant to service areas.
2. Determine the maximum pressures that can be withstand by the pumps in the purification plan and boosters stations.
3. Determine the maximum pressures than can be withstand by the transmission pipes line and its components, especially the different valves. The maximum pressure is the operating pressure added to it effect of water hammer.
4. Draw the hydraulic inclination line.
5. Determine the points at which the pressure in the transmission pipes line decreases to about 10 m water in case of using on-line booster. These points are selected as chosen locations for the boosters.
6. Determine the points at which the pressure in the transmission pipes line decreases to about 5-8 m water, then construct a ground tank for the booster to suck from it.

2-1 Ground Tank

1. Location of the ground tank is selected according to the above study at the point at which the pressure in the transmission pipes line decreases to about 5-8 m water to fill the tank

2. Capacity of the ground tank:

Capacity of the ground tank is estimated according to the following factors:

2-1 Repair period of a break in the transmission pipes line before tank location.

2-2 Repair period of a mechanical or electrical fault at the plant before the tank location, whether the purification plant or the pumping station.

2-3 A period of (5-8) hours for maximum consumption of the urban serviced area.

2-4 A period of (16-24) hours for maximum consumption of the rural serviced area.

2- Mechanical Design

2-1 Pumps

Centrifugal Pumps

Different types of the centrifugal pumps are used in water lift works in water purification plants and their boosters and in groundwater wells.

2-1-1 Pumps Selection

Pumps selection and determination of their type depends on the following factors:

Type of the handled water	: Raw- treated- groundwater
Shape	: Vertical- Horizontal
Location in the sum	: Dry well, vertical or horizontal
	Wet well, vertical, suspended or submersible.
Flow	: Quantity of water pumped by the pump across the cross section area of pump discharge pipe per unit of time. It is measured in m^3/hour or liter/second

Head : Is the used mechanical power transferred from the pump to the water required to be pumped. It is measured in atmospheric pressure (atm) or in kilo Pascal (Kpa) or by measuring the water column in meter (M.W.C).

2-1-2 Total Dynamic Head (T.D.H)

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

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

Calculation of pump discharge pressure $H_{d.dyn}$

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

$H_{st.d}$ = Static height measured between pump axis and upper tank surface

$h_{f.d}$ = Friction loss in discharge pipes = $f \frac{L}{d} \frac{Vd^2}{2g}$

h_{md} = Secondary losses in discharge pipe components (such as valves, reducers, etc)

$= \Sigma K \frac{Vd^2}{2g}$

$h_{v.d}$ = Velocity loss in discharge pipe = $\frac{Vd^2}{2g}$

Calculation of the negative pressure in suction pipe

$$H_{s.dyn} = H_{st.s} + h_{f.s.} + h_{ms} + h_{v.s.} \quad (2)$$

Where:

$H_{st.s}$ = Static height measured between pump axis and sump water surface

$h_{f.s}$ = Friction loss in suction pipes = $f \frac{L}{d} \frac{Vd^2}{2g}$

h_{ms} = Secondary losses in suction pipe components

$$= \Sigma K \frac{Vd^2}{2g}$$

$h_{v.s}$ = Velocity loss in suction pipe = $\frac{Vs^2}{2g}$

2-1-3 N.P.S.H.

It expresses minimum suction cases required to prevent cavitation phenomenon in the pump. It is the energy required to pump the liquid to pump impeller to avoid cavitation and flash. It is divided into NPSH (reef) and NPSH (av).

NPSH required or minimum is determined by test and usually determined by the factory. While NPSH available is determined at the site and must equal at least to NPSH required to avoid cavitation phenomenon and its increase provides safe limit against cavitation. It is calculated as follows:

$$NPSHav = (H_{abs} - H_{vap}) + H_{st.s} - H_f - \Delta h_{dyn}$$

Where:

H_{abs} = Absolute atmospheric pressure at water surface in the sump.

H_{vap} = Water vapor pressure sucked at pump center (at operating temperature)

= 0.03 kg/cm^2 at 20°C.

$H_{st.s}$ = Static height measured between pump axis and sump water surface

H_f = Sum of friction loss and secondary losses in suction pipe and its components.

Δh_{dyn} = Decrease of dynamic pressure in pump impeller.

Note: All pressure units in the equation are in water meter

In case of increase of NPSH (req) than NPSH (ava), a pump with less speed is used, and vice versa.

Fig (2-1) shows calculation of NPSH

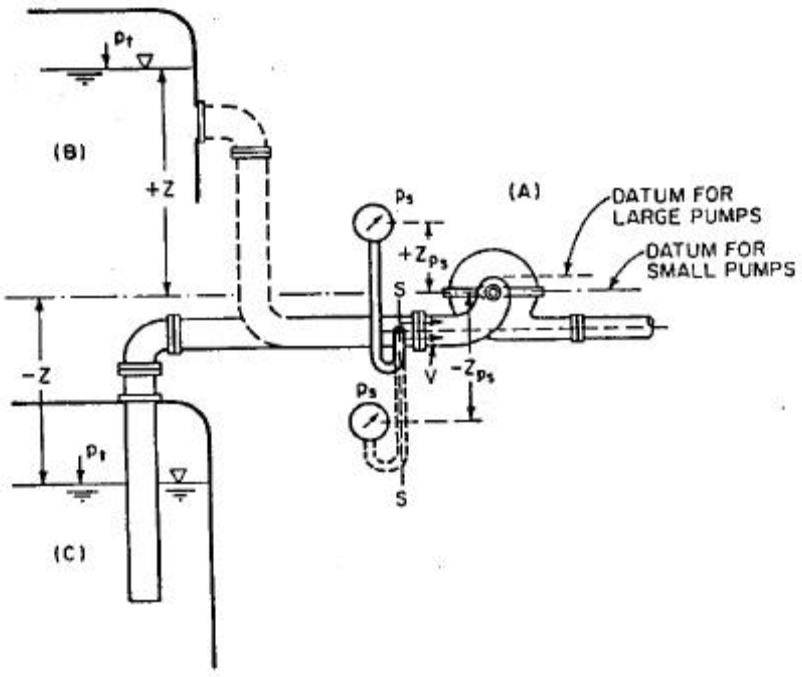


Fig (2-1): Schematic diagram for NPSH calculation

2-1-4 Decrease of dynamic pressure Δh_{dyn}

Decrease of dynamic pressure is produced from increase of speed at the rear face of impeller blade, which in proportion with the specific speed at the inlet of the impeller and depends on barometric pressure of the pump H_m.

$$\Delta h_{dyn} = \sigma \ Hm$$

Where σ = THOMA cavitation coefficient

Metric 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) and a bell mouth is installed at its inlet, and must use also large diameter to decrease speed loss.

   Flow meter must not be installed on suction pipe.

2. Head range: Low head 3-12 water meter

   Medium head 15-45 water meter

   High head 45-150 water meter and more.

Centrifugal pumps with single or double suction inlet are used for medium and high head, while mixed and axial pumps are used for low head.

- Speed Low speed 500-750 rpm

  Medium speed 1000-1500 rpm

  High speed 3000 rpm

Specific Speed Is the speed at which pump flow is 1 m^3/sec with head 1 water meter at maximum efficiency.

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

Where:

N = Pump speed (rpm)

Q = Pump flow (m^3/sec)

H = Total head of the impeller (water meter)

2-1-5 Type of Impeller

Type of the impeller is selected according to specific speed and the following numbers:

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

The above is for end suction impellers. Half value of flow can be calculated from specific speed equation when using double suction impellers. Total head of the pump can be divided into group of stages.

Fig (2-2) show approximate shape of the impeller according to the approximate limits of specific speed change range.

2-1-6 Pump parts metal type

Pump impeller and accessories metal type is determined according to type and nature of the used water. For raw water clear from sands and neutral hydrogen ionized treated water, impellers, shaft protection bushes and wear rings are made from phosphor bronze, while for groundwater with high alkaline or high acidity, impellers and accessories are from stainless steel. For water with sands or high

sludge that causes wear and corrosion, the impellers are made form cast or ductile iron and wear rings are made from stainless steel.

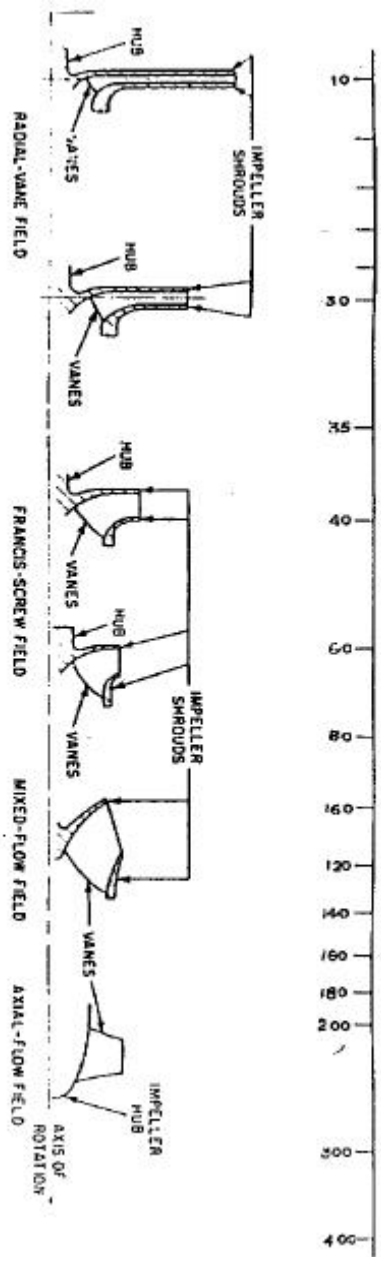


Fig (2-2): Impeller shape is changed according to approximate limits of specific speed change range

2-1-7 Pump Characteristic Curve

At fixed speed of the centrifugal pumps, pump flow Q increases as the head H decreases, and vice versa. Therefore, these pumps are self regulating capacity. Internal power P, efficiency η and NPSH req depend on the capacity.

The relation connecting all of these parameters is called Pump Characteristic Curve, which illustrates pump operating features.

Pump operating conditions determine if it is better to use flat curve or steep curve. In case of steep curve, pump capacity has lesser change than in case of flat curve under same conditions of differential head.

Pump manufacturers supply many characteristic curves for each individual pump, because pump enclosure can accommodate impellers with different diameters affect the flow and the total head of the approximate relation between each of them and impeller diameter as follows:

$$Q \alpha D^2 \ , \ H \alpha D^2$$

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

$Q \alpha N$, $H \alpha N^2$, $P \alpha N^3$

Fig (2-3) illustrates characteristic curves of centrifugal pumps for different impeller diameters

Shape of the characteristic curve depends on the following:

A- Pump type (impeller- pump screw enclosure)

B- NPSH, manufacture accuracies, capacity, nature properties of the lifted liquid (viscosity)

C- Curvature of the curves changes according to specific speed of different types of impellers as follows:

- By increasing the specific speed, inclination of QH curve becomes steeper, while efficiency curve becomes peaky and the power reaches to its maximum value at shut-off point.
- By decreasing the specific speed, inclination of efficiency curve becomes flat and power curve reaches to its minimum value at shut-off point $Q = 0$

2-1-8 System Head Curve

The system consists of pipes, its components and different valves and can add to them open channels and heirs and can also include measuring devices and equipments operating with liquids, tanks, etc.

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

Start point of system head curve shows the difference of static levels (between water level in intake sump and upper level in the tanks receiving the lifted liquid).Calculation of frication losses in the pipes and all the secondary losses in the system is started according to the different flows from minimum pumps flow to

maximum flow that the system withstands. Different points are plotted to draw the head curve.

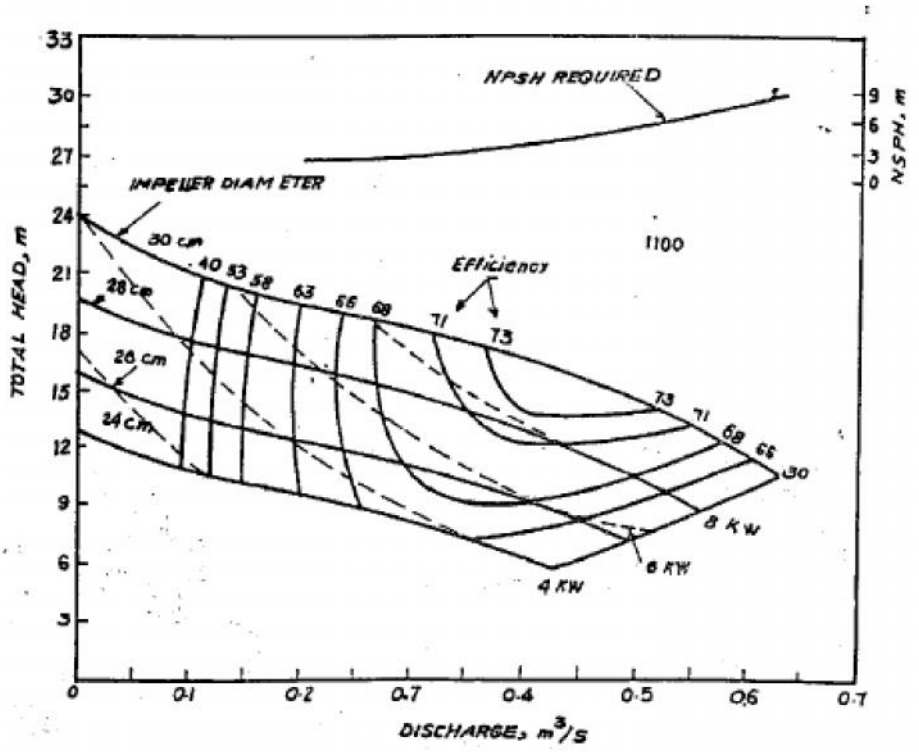


Fig (2-3): Characteristic curves of centrifugal pump for different impeller diameters

Fig (2-4) illustrates system head curve consists of suction tank (1), discharge tank (2), pump and pipes line between them and its intersection with pump head curve.

If there is difference in water level in take sump (suction), system head curve must be drawn at minimum and maximum water level in the sump.

Fig (2-5) illustrates system head curves at minimum and maximum water level in the sump and its intersection with pump head curve.

Note:

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

2-1-9 Duty (Operating) Point

Duty operating point B will be determined for each pump, which is the point of intersection of pump curve (Q-H Curve) and system (piping) curve H_A, fig (2-6). This point is not changed (and hence the flow Q and the head H) for the pump unless the pump speed n, impeller diameter D or system characteristic are changed as illustrated in Fig (2-3), Fig (2-17) and Fig (2-18).

Fig (2-8) illustrates head curve of the system shown in Fig (2-7) which is consists of suction tank, pump, main pipes line D and the branch lines A, B and C, each of them ends to discharge tank and intersected with pump head curve.

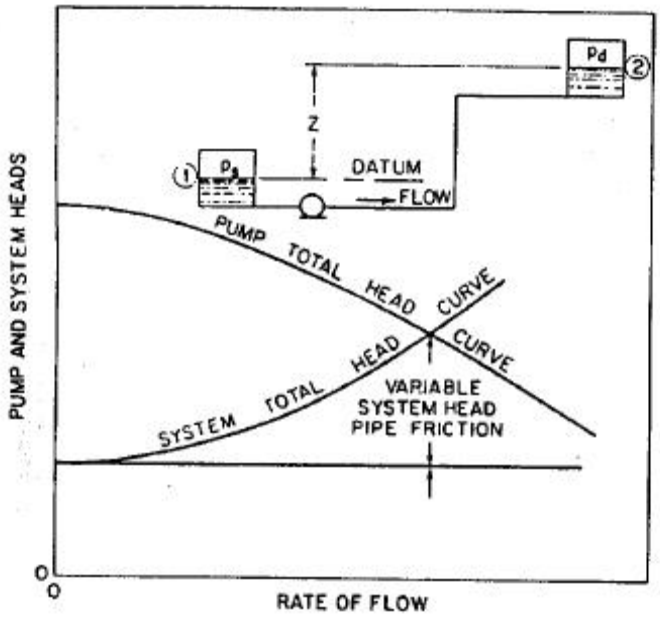


Fig (2-4): Head curve of the system consists of suction tank, discharge tank, pump and pipes line between them

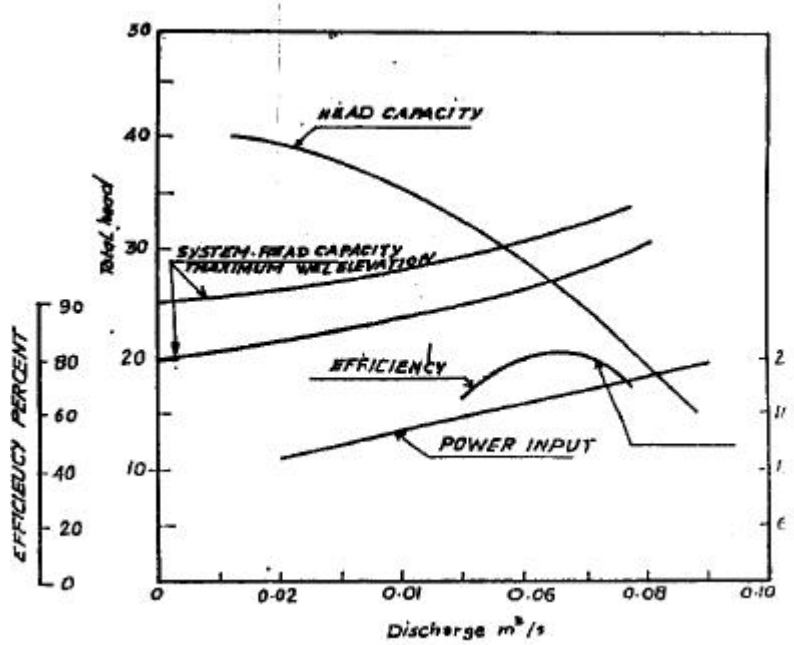


Fig (2-5): System Head Curves at minimum and maximum water level and their intersection with pump head curve

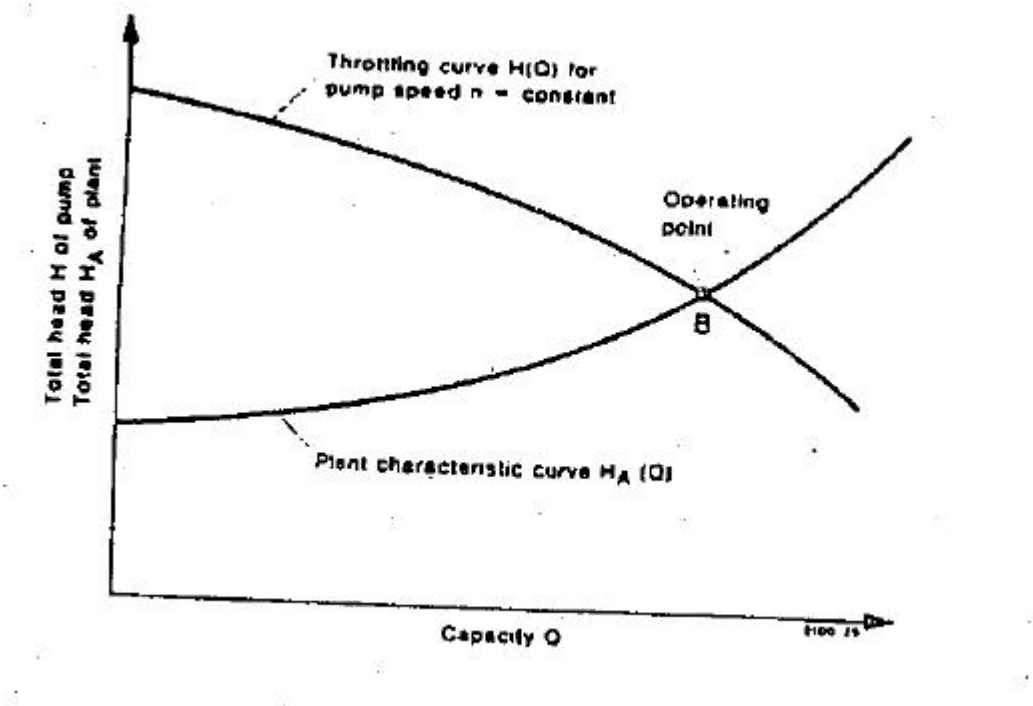


Fig (2-6): Intersection point of system head curve with throttling curve

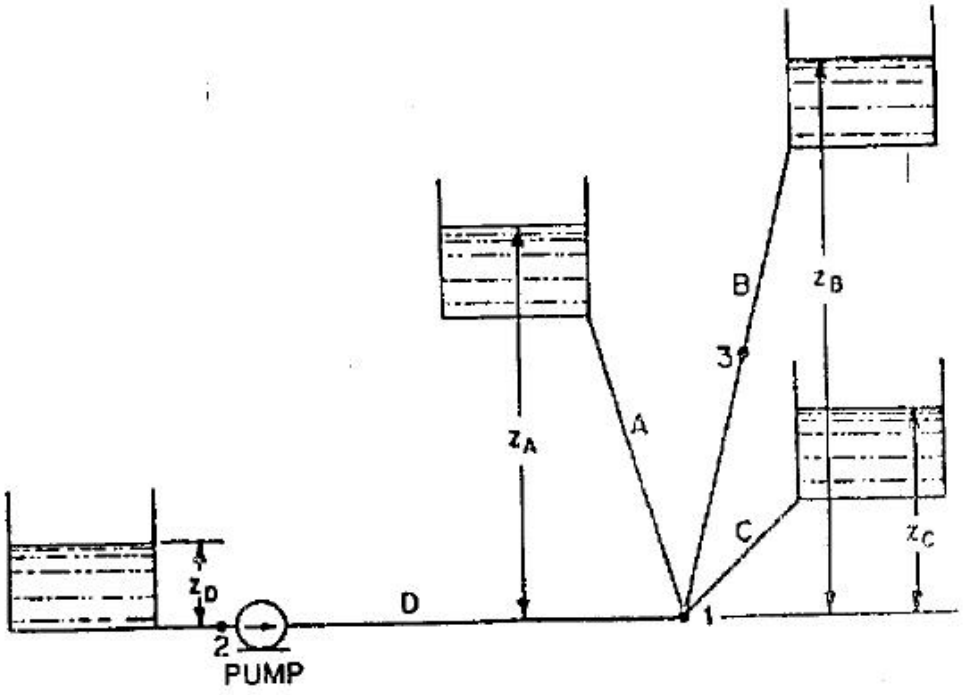


Fig (2-7): System consists of suction tank, main pipes line and different branch lines each of them ended to discharge tank

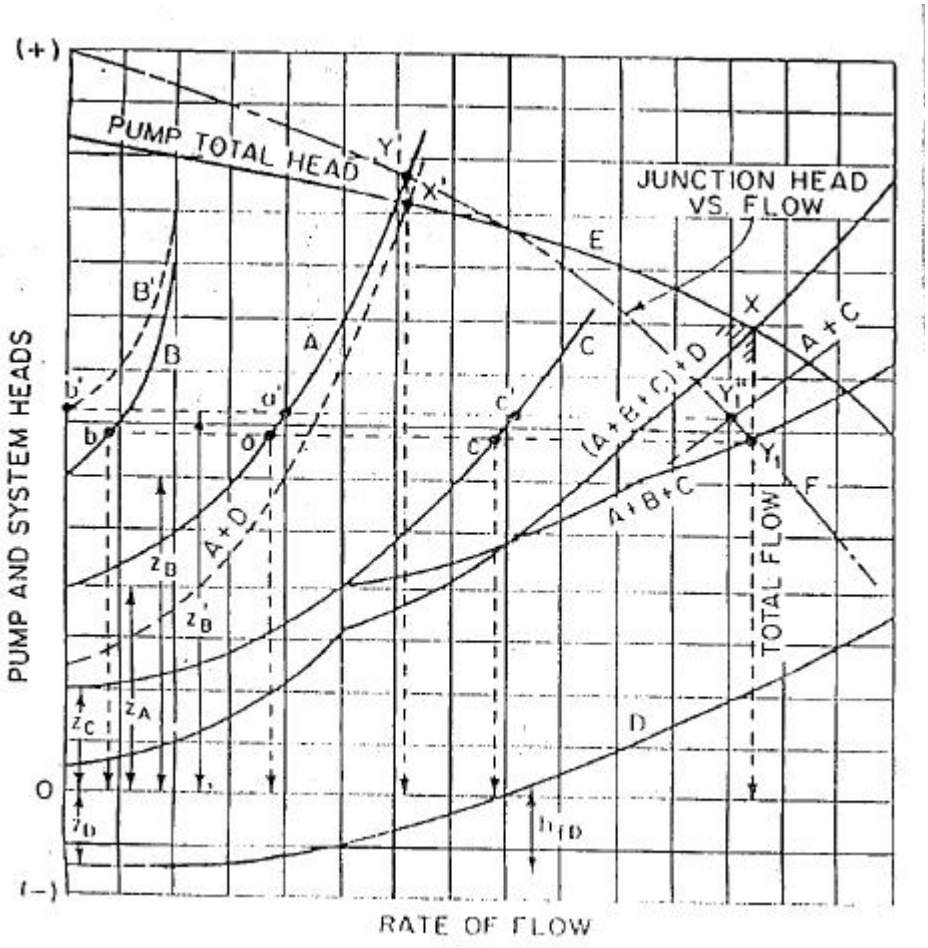


Fig (2-8): Head curve of the system illustrated in Fig (2-7)

2-1-10 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 (2-9) 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.

2-1-11 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 (2-10).

$H = H_1 = H_2 = H_3 =$ .....

$Q = Q_1 + Q_2 + Q_3 =$ .....ete

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).

$Q = Q_1 = Q_2 = Q_3 = ...$

$H = H_1 + H_2 + H_3 = ...etc$

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

Fig (2-12A) 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).

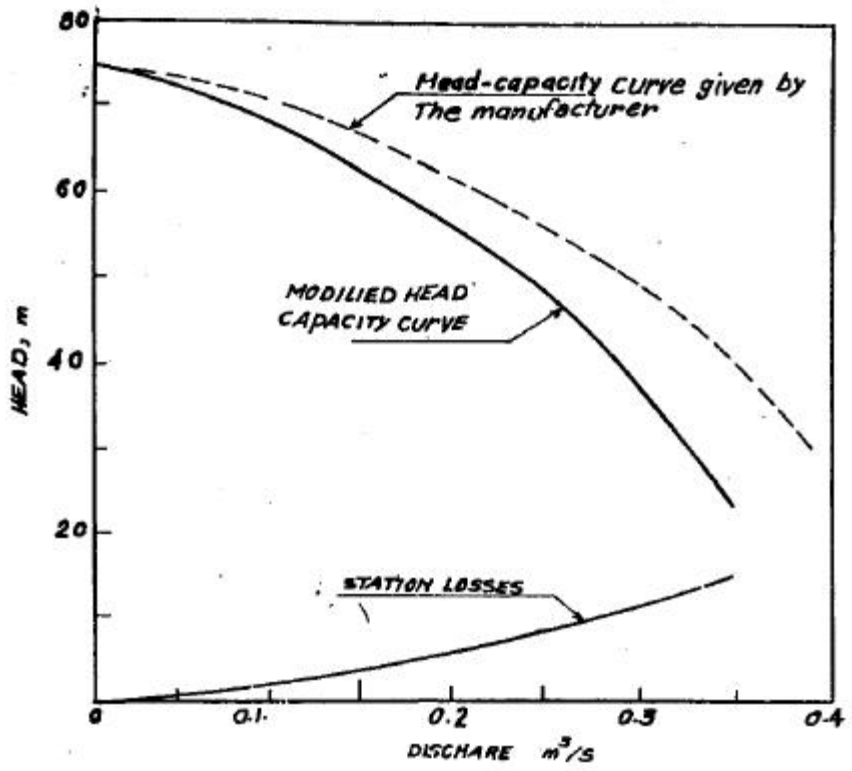


Fig (2-9): Modified head curve

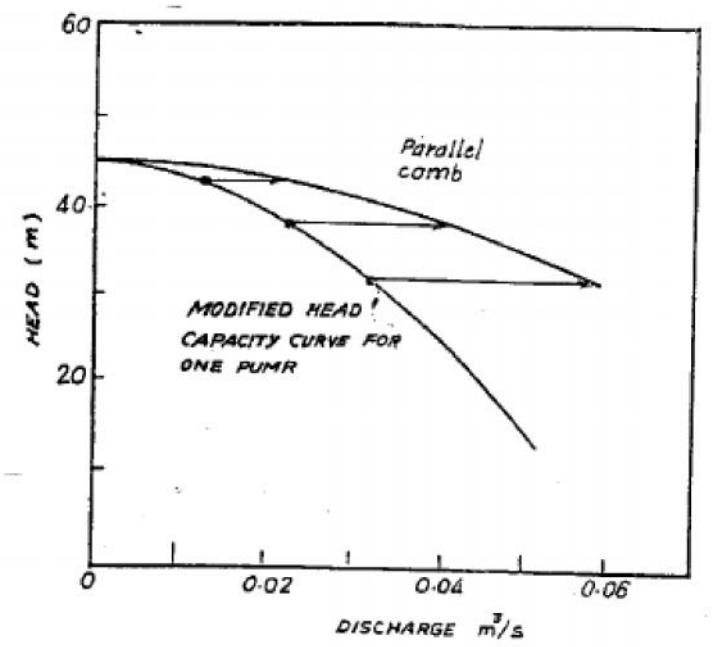


Fig (2-10): Operation in parallel curves

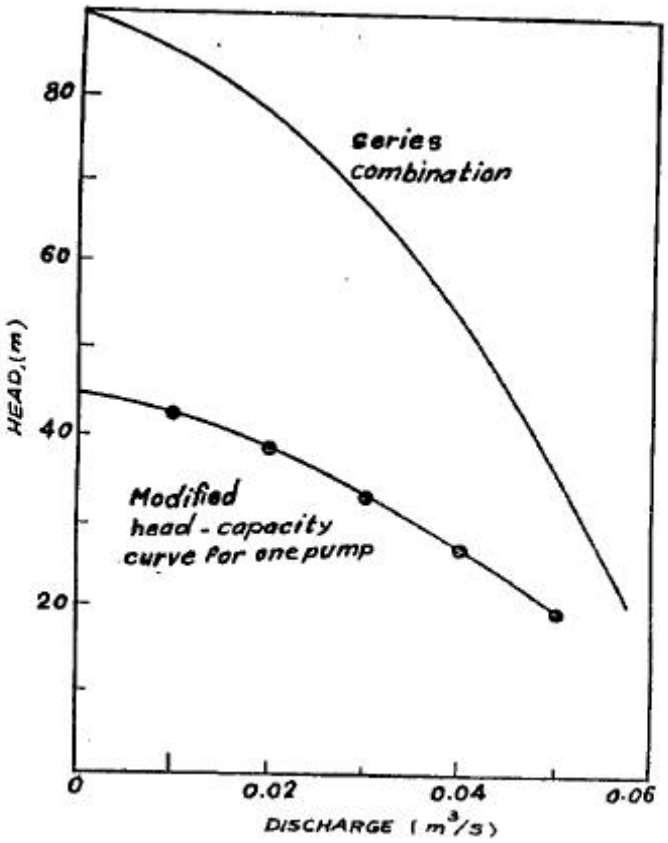


Fig (2-11): Operation in series curve

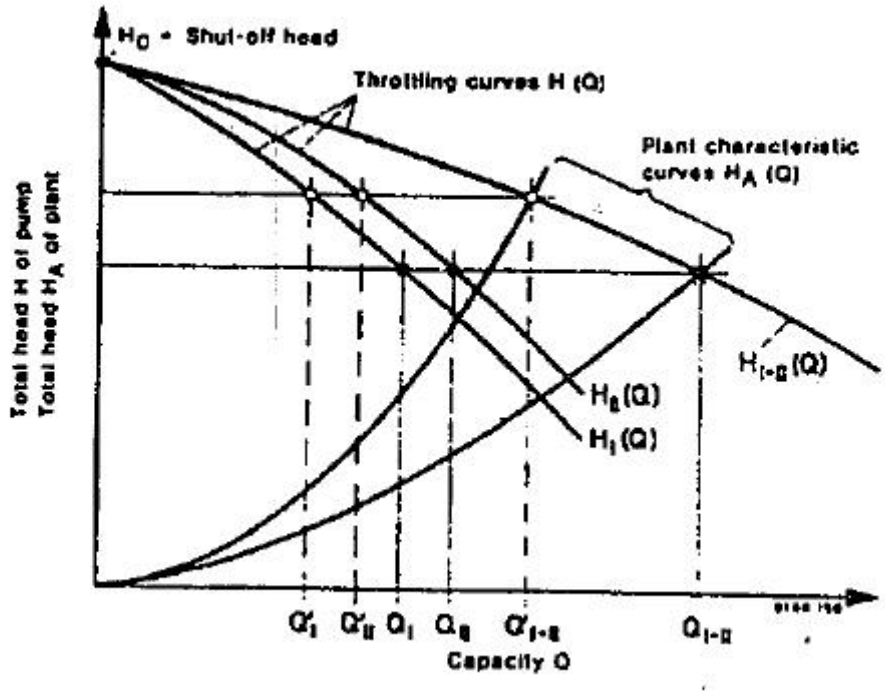


Fig (2-12A): Curve of operation of two combined pumps in parallel

Fig (1-12A) illustrates head curve of three equal pumps combined in parallel and their head curves.

Fig (2-13) 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 (2-14) 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 (2-15) 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).

Note:

From the above figures, it is clear that:

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

Fig (2-16) 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.

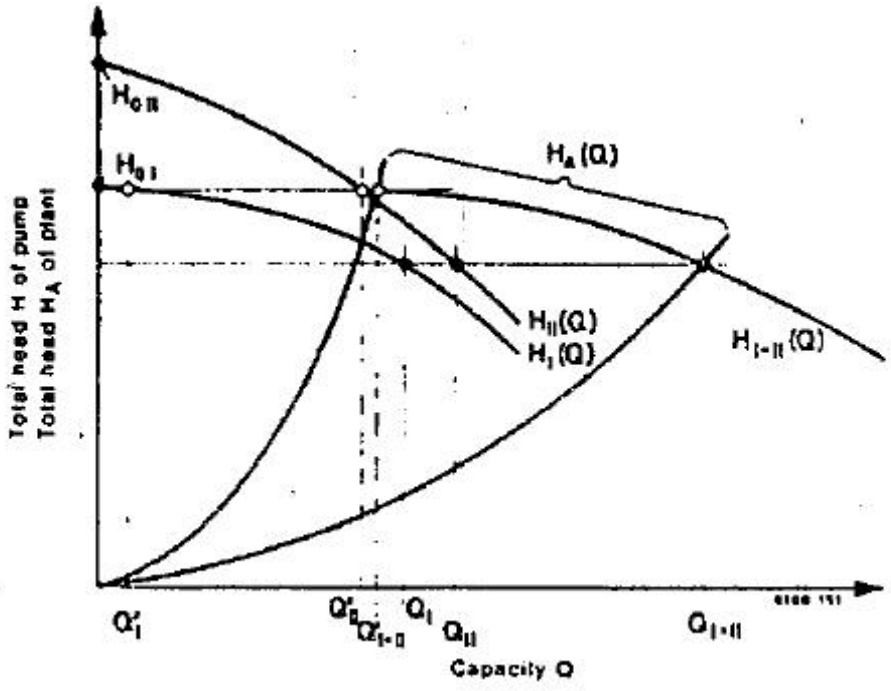


Fig (2-13): Head curve of two pumps individual and combined in parallel and have different heads

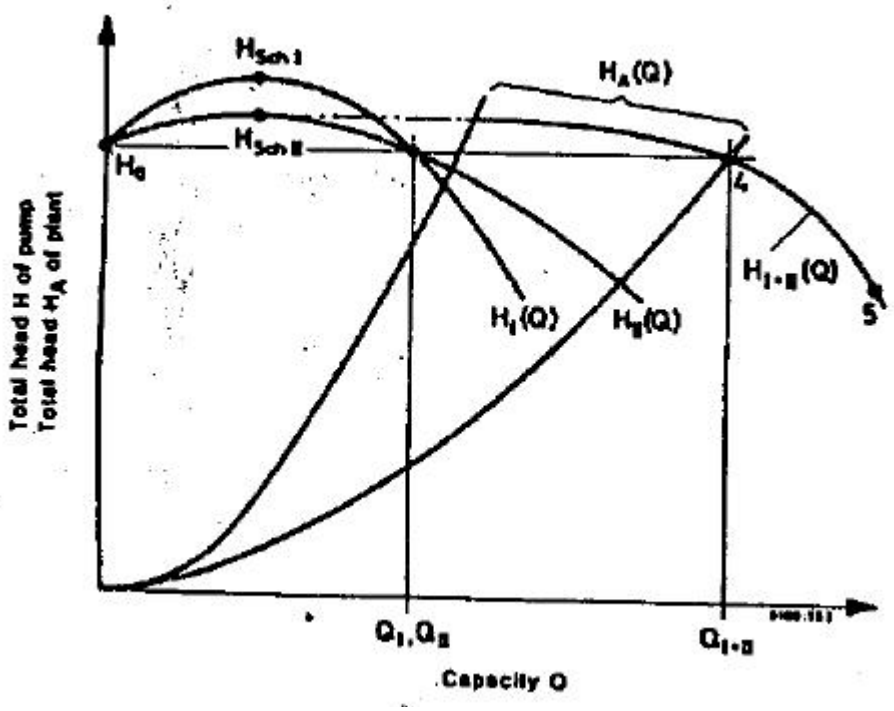


Fig (2-15): Head curves of two pumps combined in parallel have different properties and head of each pump is different

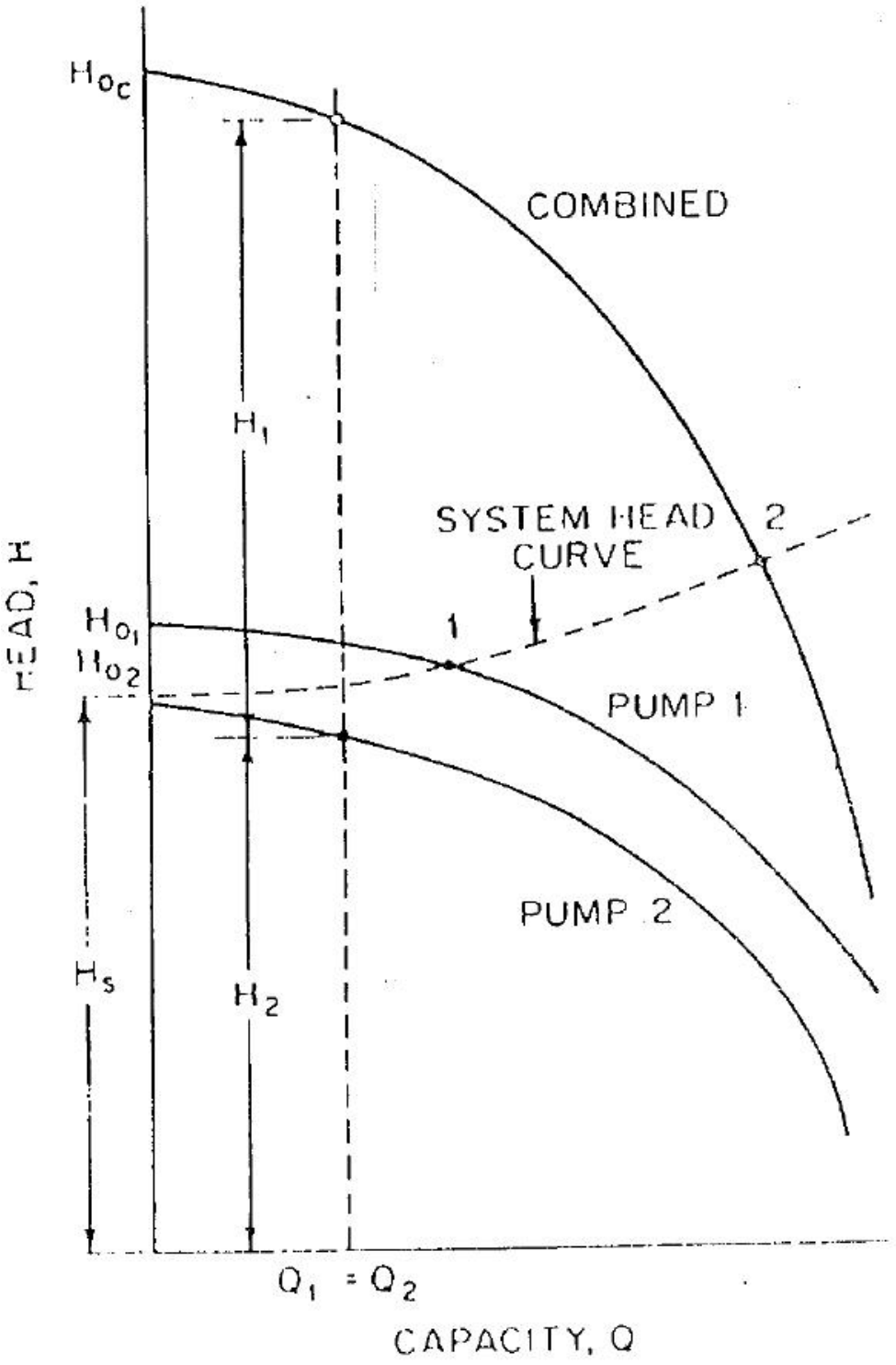


Fig (2-16): Head curves of two individual and combined pumps in series

2-1-12 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 η_{mot} = Electrical motor efficiency

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

2-1-13 Efficiency

Pump total efficiency =

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

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

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

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

$$\eta_{Total} = \eta_{mot} \cdot \eta m \cdot \eta H$$

- Total efficiency of the pumps operating in parallel

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

Where:

ΣQ= Sum of pumps flow (liter/sec)

ΣP = 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

2-1-14 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. Fig (2-17) illustrates pump Q-H curve and the different system curve resulted from the control of throttle degree of discharge valves.

Fig (2-18) 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)
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)

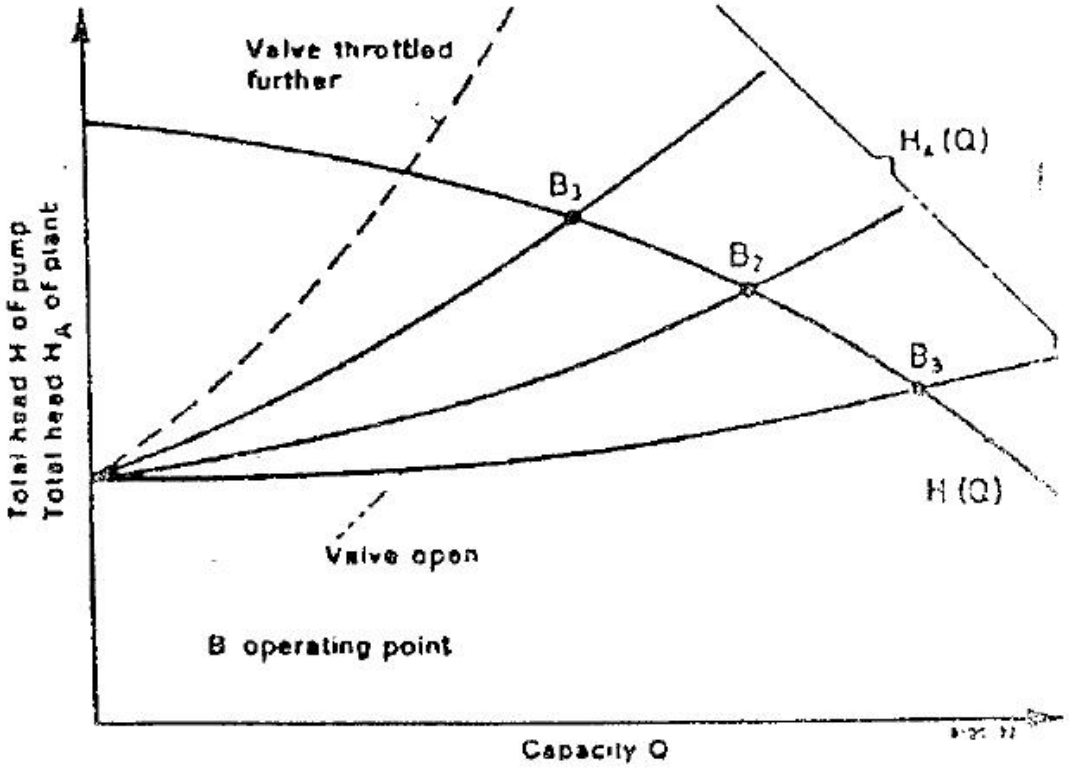


Fig (2-17): H.Q pump head curve according control in discharge valve throttle

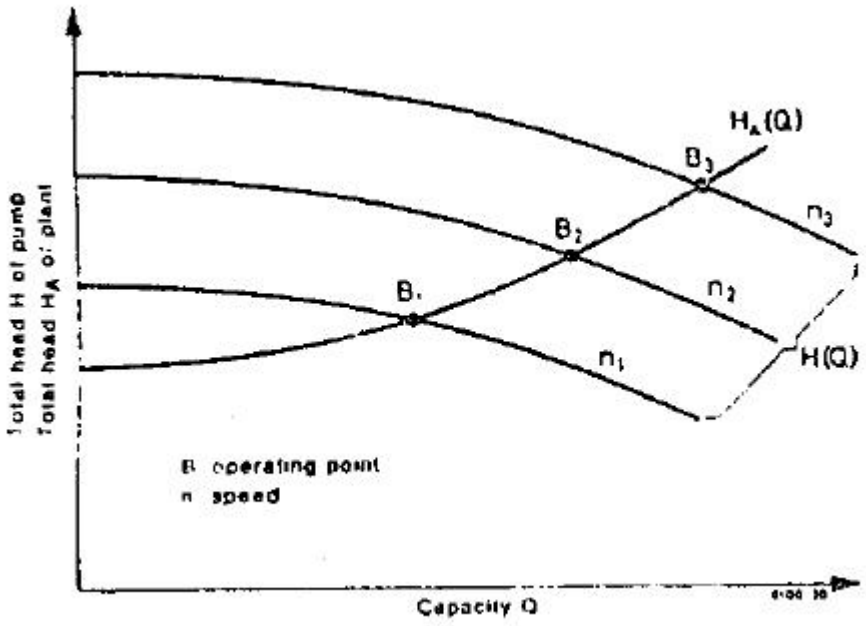


Fig (2-18): Change of operating point by change of pump speed

Fig (2-19) illustrates modification of pump head curves H-Q and P-Q as a result of changing impeller blade inclination angle.

Fig (2-20) 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 (2-21) 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.

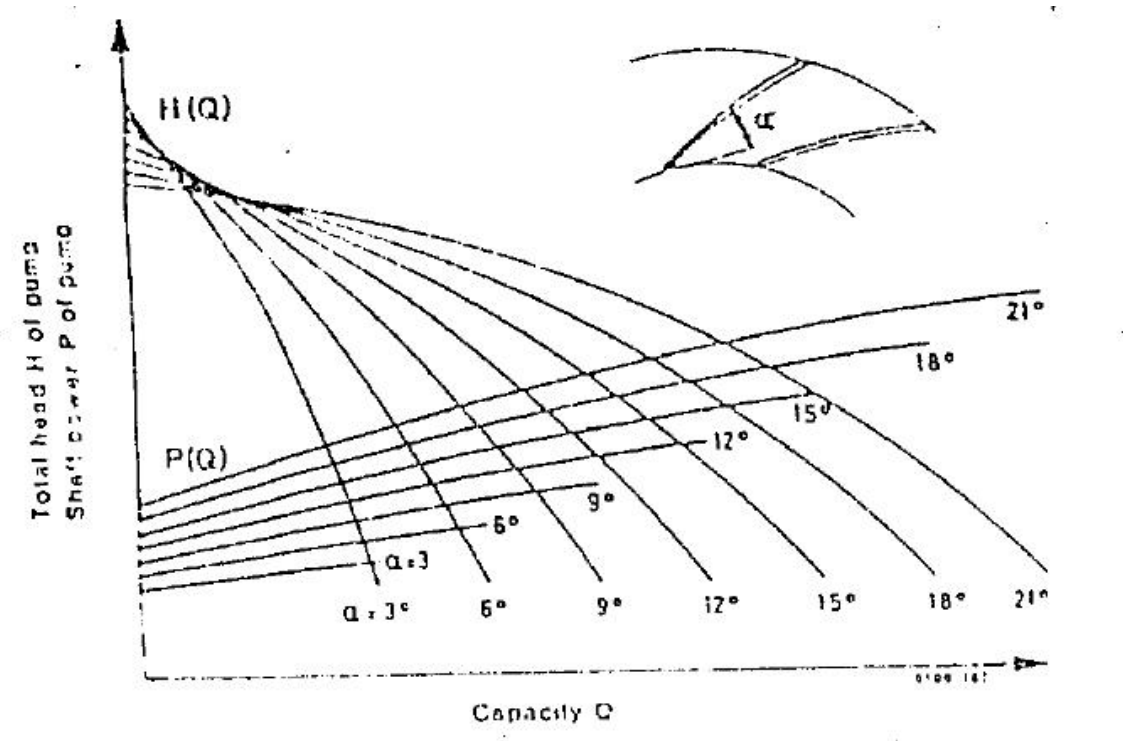


Fig (2-19): Change of characteristic curves by changing blade inclination angle

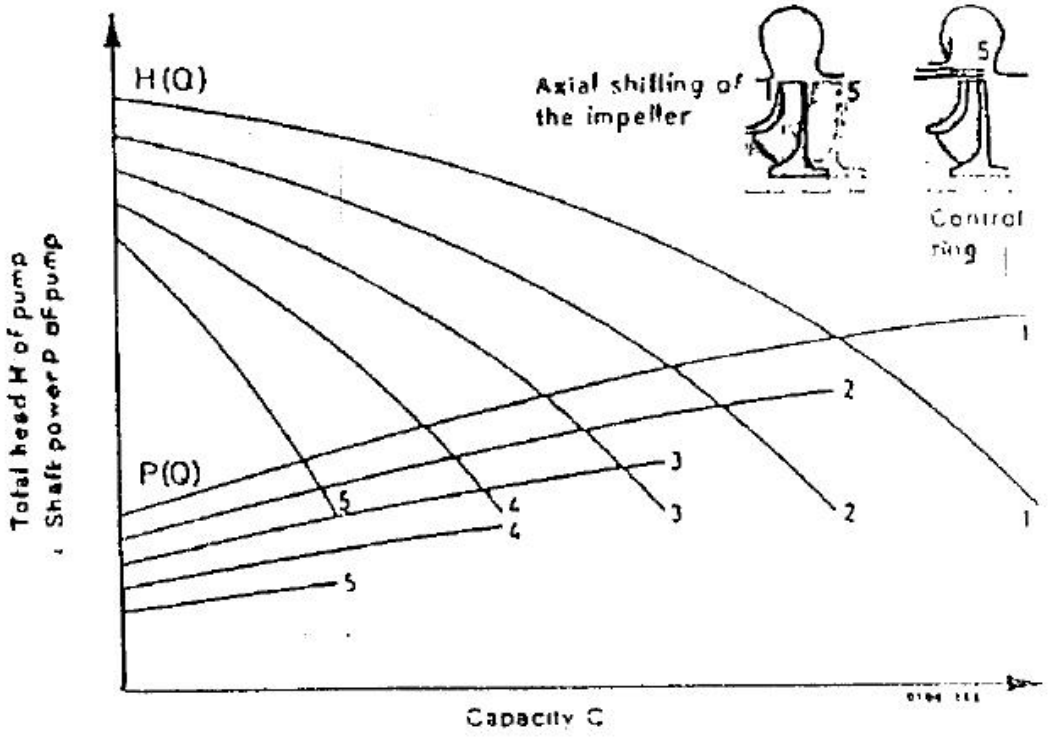


Fig (2-20): Change of characteristic curves as a result of changing impeller position on the shaft or addition of sealed cover at screw enclosure inlet

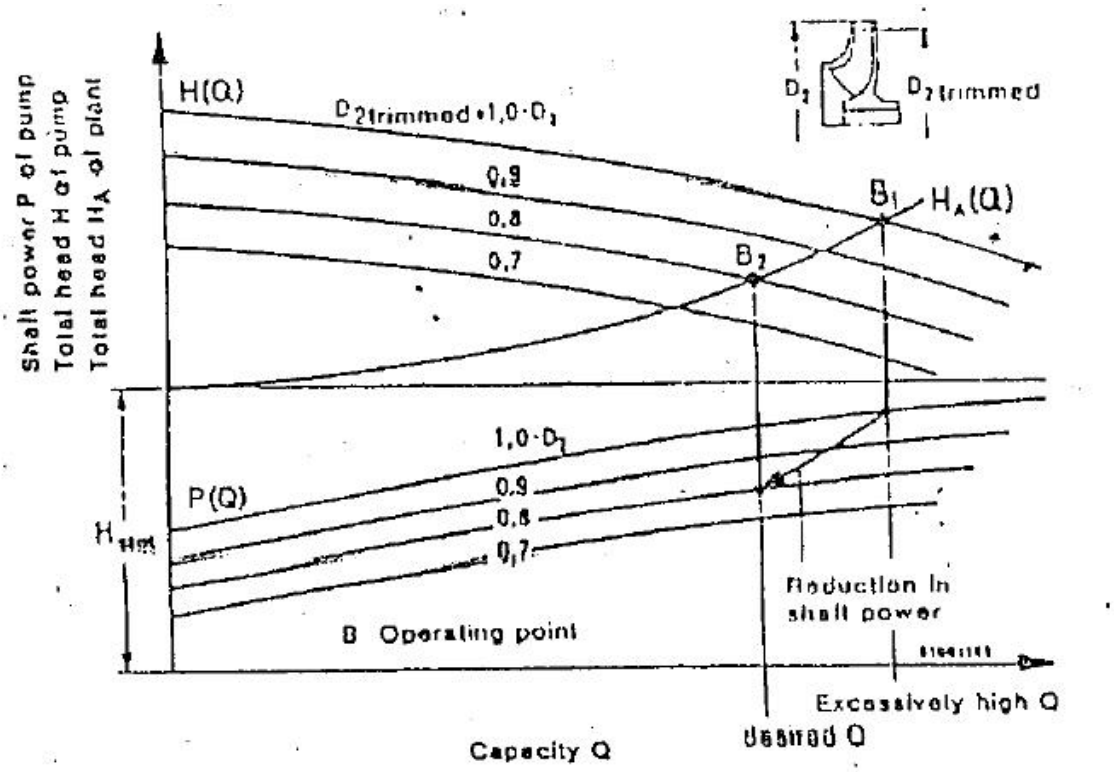


Fig (2-21): Change of characteristic curves as a result of changing impeller diameter by trimming

2-1-15 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:

$$H_S = H_A - (H_v + h_v + H_f + H_m)$$

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_s Vapor Head = 0.03 kg/cm^2 at temperature 20°C

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:

2-1-15-1 Priming Means

2-1-15-1-1 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.

2-1-15-1-2 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.

2-1-15-1-3 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.

2-1-15-1-14 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:

$$T = \frac{V}{Qs} . f$$

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

2-1-16 Types of the used pumps

2-1-16-1 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.

2-1-16-2 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.

2-1-16-3 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.

2-1-16-4 Volute Pumps

These pumps are used suspended for sludge lift.

2-1-16-5 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.

2-2 The Sump

Selection of pumps suction pipes dimensions in the sump depend on pump maximum flow Q.

Also, selection of sum dimensions depend on water velocity inside pipes line supplying the sump V_P

Fig (2-22) illustrates the relation between pump flow in Liter/sec and the standard dimensions of the sump in cm.

Fig (2-23) illustrates schematic for the sump showing standard dimensions used in Fig (2-22).

Figures (2-24, 2-25, 2-26 and 2-27) show some schematics for the sumps recommended to be used with the conditions listed next to each of them.

The dimensions shown in the figures are the standard dimensions that prevent formation of forced fountains and pump noise and vibrations. If pump manufacturers submit different dimensions and the select of the pump is correct, it must decrease pump speed or increase sump depth, whichever is less expensive.

If it is hard to install elbow at the beginning of suction pipe and the inlet of the suction pipe become horizontal, minimum depth of water in the sump S, Fig (2-238) (the distance between water surface in the sump and the internal upper trace of suction pipe) must be determined such that:

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

Where:

d_i = Internal diameter of suction pipe (cm)

V_P = Velocity in suction pipe (cm/s)

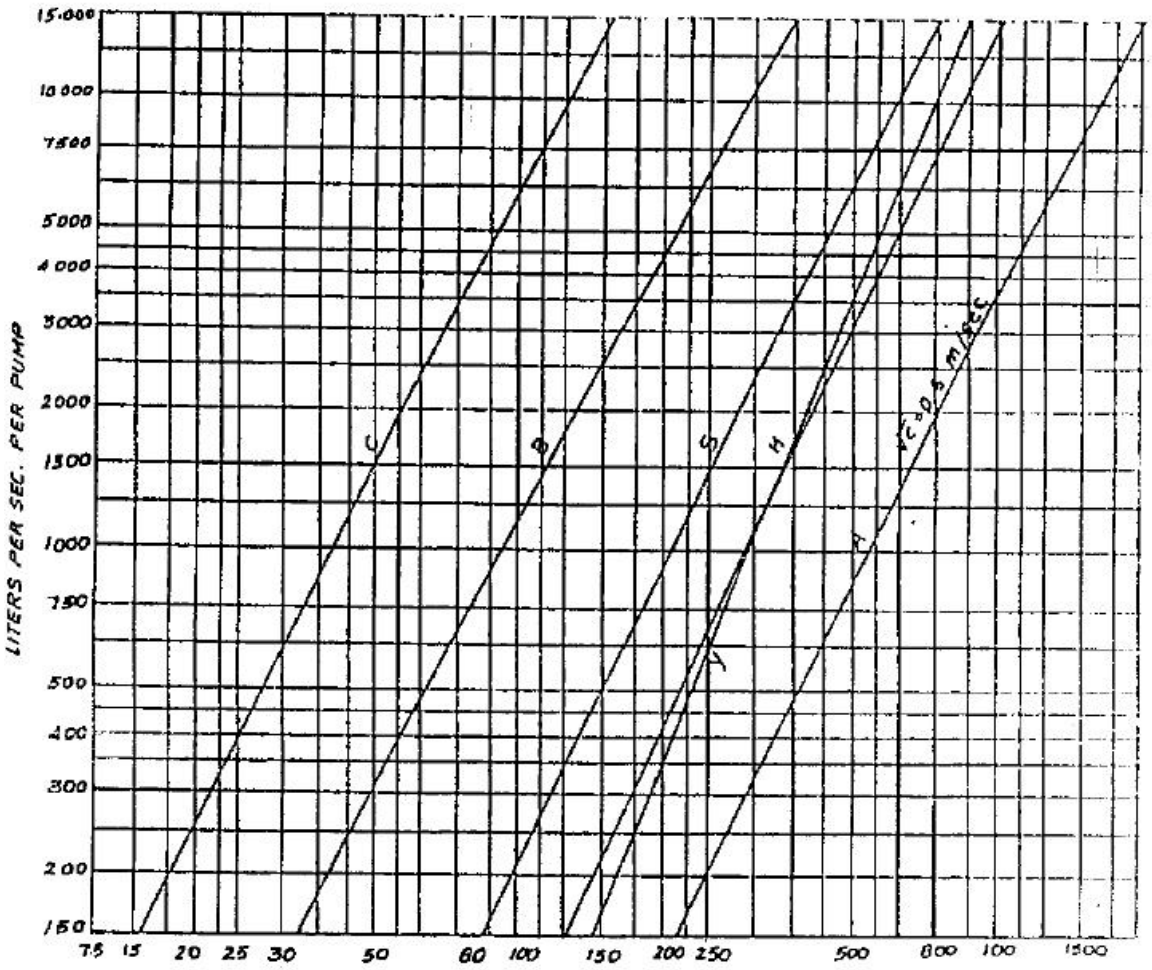


Fig (2-22); Relation between pump flow (l/s) and standard sump dimensions (cm)

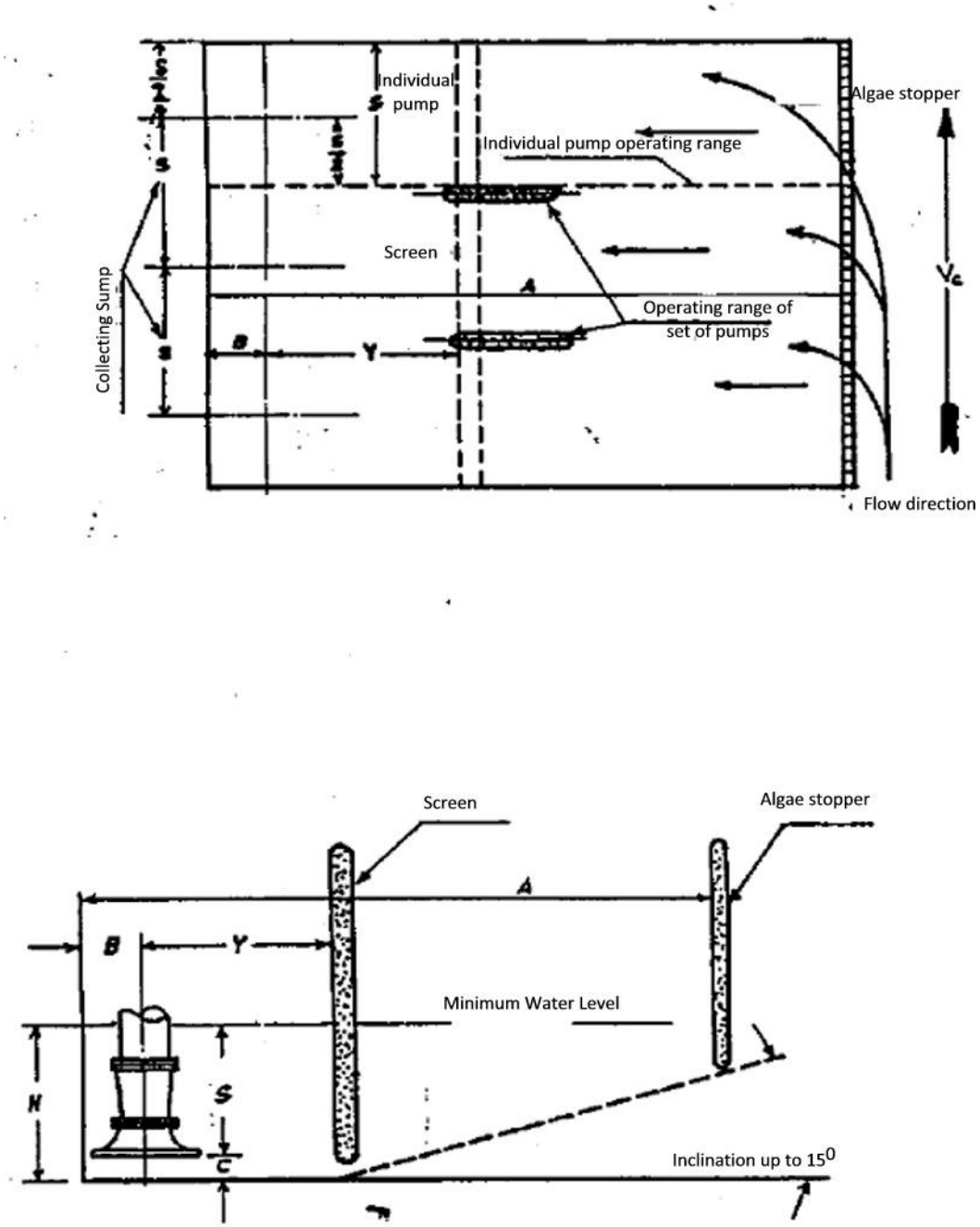


Fig (2-23): Schematic shows the standard dimensions used in Fig (2-23)

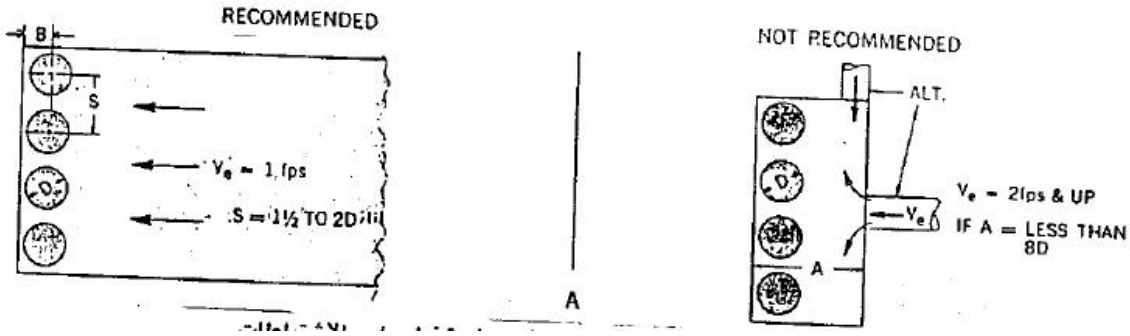


Fig (2-24): Some sump schematics recommended to be used with the conditions indicated next to each of them

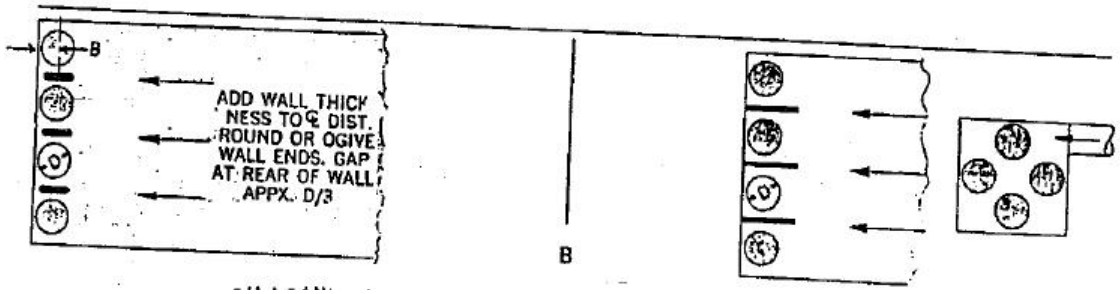


Fig (2-25): Some sump schematics recommended to be used with the conditions indicated next to each of them

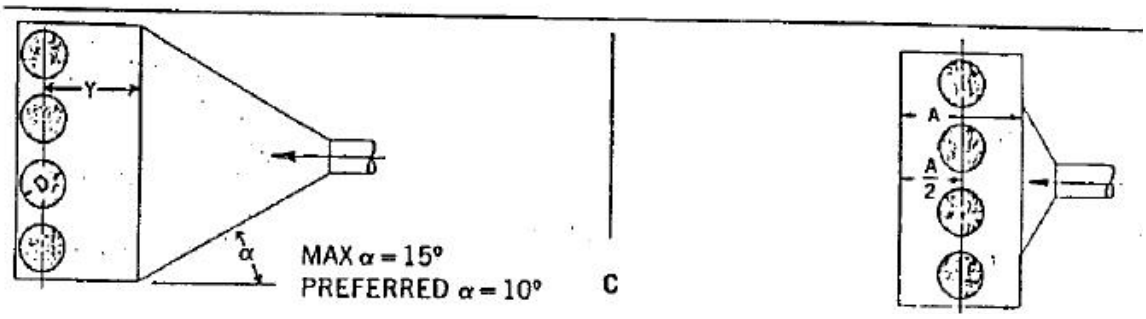


Fig (2-26): Some sump schematics recommended to be used with the conditions indicated next to each of them

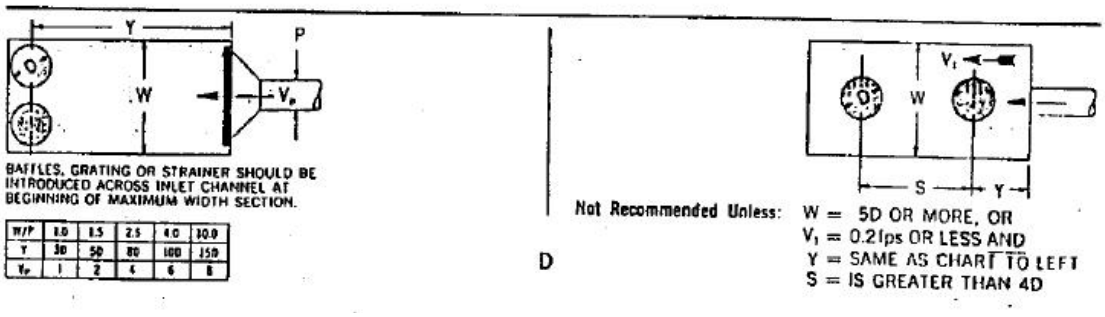


Fig (2-27): Some sump schematics recommended to be used with the conditions indicated next to each of them

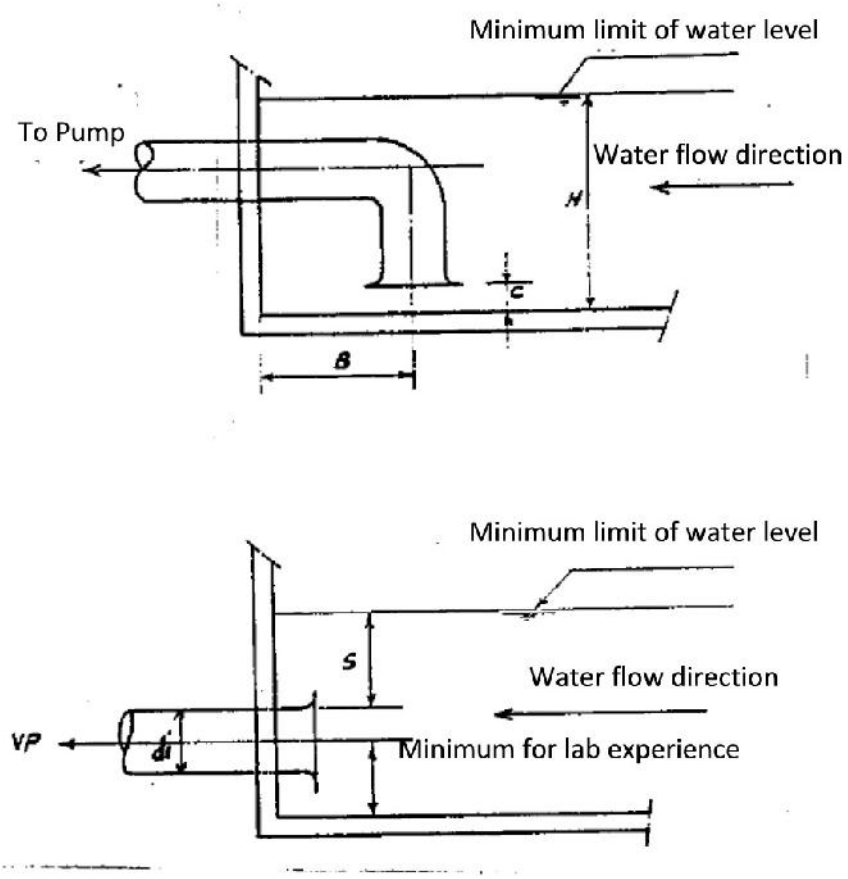


Fig (2-28): Minimum depth of water in the sump

2-2-1 Velocity in suction pipe V_P

Bell mouth must be used at the beginning of suction line to reduce the loss at inlet (in general, the good design is the design that provides safe operation in terms of the head required from the pumps and the velocity as follows):

Required head from the pump	Velocity in suction pipe
4.5 m	0.76 m/s
Up to 15.00 m	1.2 m/s
More than 15.00 m	1.67 m/s

2-2-2 Velocity in suction sump (Approach Velocity)

Velocity of 30 cm/s is considered ideal velocity for the water in suction sump to approach from pumps suction pipes and must not exceed 50 cm/s.

By knowing maximum flow required for all pumps operated at peak hour at ideal approach velocity, vertical cross section of water in the sump is calculated that provides the best inlet and approach conditions at all levels of water, then dimensions required for the sump are selected.

2-3 Chlorination

Purpose of chlorination process

Purpose of chlorination process is limited in oxidation of algae and harmful micro-organisms causing diseases such as bacteria, normal and shells microbes of specific doses in stages of purification process so as not to cause any harms to human or animal health and without causing any change in color, taste and odor of water to be re-added at the boosters to prevent pollution that may exit in water network and compensate lack of the remaining chlorine. Chlorine is the easiest, cheapest and more commonly used materials in this regard in drinking water boosters.

Design Criteria

Chlorine dose required to be added to water in its three stages is calculated a follows:

It is added to the purified water after performing chlorine demand test for half an hour and the remaining chlorine is measured after contact of not less than 20-30 minutes. The required dose is determined so as the remaining chlorine at the end of the network is not less than 0.20 ppm, and an additional percentage is added to prevent the pollution that may exist in water network. Another percentage can be added in the network to compensate lack of the remaining chlorine.

2-3-1 Chlorine addition devices and equipments

Chlorine addition unit consists of the following devices and equipments:

1. Chlorine solution injection devices and equipments.

They are from parallel cylinder or to use the evaporator according to the following table:

Cylinder capacity (kg)	50	500	1000
Maximum suction (kg/h)	1	8	10

If air temperature is decreased less than 10°C, it is recommended to operate handling cylinder to ensure non-icing of the cylinders. Cylinders must never subject to direct flame or heating the walls and can use water bathes for handling cylinders in case of decrease of air temperature.

All cylinders are provided with safety fuses whether on the valves or at the bottom of the cylinders. These fuses are opened automatically at temperature rise more than certain limit. Cylinders must be selected by any of the internationally adopted inspection offices once each two years at least, and it is not permissible to be filled with the gas unless obtaining inspection and test certificates, such as:

- Liquid pressure test
- Air pressure test
- Buckling test.
- Valves safety tests.

Evaporators are used when the quantity of the chlorine required being sucked from the cylinder reaches 75 kg/h for transformation of chlorine from liquid to gas by evaporation chamber inside water or oil bath heated by submersed electrical heater. The gas exits from evaporator exit hole to addition devices.

Evaporators are provided with set of control devices, water level and temperature meters or gas and pressure meters, and measuring devices to secure the operation.

2. Chlorine gas injection devices.
3. Chlorine cylinders.
4. Injectors.
5. Injection pumps.
6. Injection devices in pipes and tanks.

According to the following details:

1- Chlorine solution devices and equipments

It consists of:

1A- Solution preparation tanks.

1B- Metering injection pumps.

1C- Connection pipes from solution tanks to injection places.

A- Solution preparation tanks

They are number of tanks for preparation of chlorine solution, such as calcium hypochlorite or sodium hypochlorite.

The solution is prepared by mixing the powder with concentration of 30-60% in case calcium hypochlorite, or by mixing chlorine solution with concentration of 0.1-1% in case of sodium hypochlorite and it is mixed by water to obtain suitable diluted solution to be injected in the unit.

Tanks must be with sufficient capacity for operation of the water purification plant for a period not less than 24 hours taking into account maintenance conditions and sudden faults. These tanks must be made from fiber glass (G.R.P), rubber, PP or any other material not affected or ionized by chlorine.

B- Injection Pumps

They are in two types, pumps with porcelain or polyethylene plunger, or pumps with rubber diaphragm. Each type has meter on discharge pipes to determine quantity of the solution discharged from the pump during a certain time (usually Liter/Hour).

C- Connection Pipes

They are from U.P.V.C or H.D.P.E or similar complete with valves and special pieces of the same pipes type, taking into account that they withstand pressure not less than 6 bar. Method of injection whether in the pipes or in the tanks, must be in conformity with what will be specified later.

2- Chlorine gas injection devices

They are in two types, pressure type and vacuum type. The second type is currently used because it is full safe, where it sucks air from the environment in case of any crack or defects in the device, therefore does not cause any leakage inside device chambers. Flow of the device is determined by kg/hour.

When selecting flow of the device, it must take into account to be sufficient for maximum required dose + 25% for emergency. It must take also into account to connect overflow of the device outside chlorine chamber at a level not affecting workers in the plant.

3- Chlorine Cylinders

They are high quality steel containers with different capacities, 50, 200, 500 and 1000 kg. The cylinder withstands air test pressure not less than 25 bar and water tests pressure not less than 45 bar taking into consideration non existence of welding at the area of connection of cylinder walls of capacity 50 kg with its base. Quantity of chlorine gas that can be sucked from the cylinder is determined according to cylinder capacity and air temperature. If one cylinder is not sufficient for the required chlorine quantity, more than one cylinder can be connected in parallel or to use the evaporator according to the following table:

Cylinder capacity (kg)	50	500	1000
Maximum suction quantity (kg/hour)	1	8	10

If air temperature is decreased less than 10°C, it is recommended to operate handling cylinder to ensure non-icing of the cylinders. Cylinders must never subject to direct flame or heating the walls and can use water bathes for handling cylinders in case of decrease of air temperature.

All cylinders are provided with safety fuses whether on the valves or at the bottom of the cylinders. These fuses are opened automatically at temperature rise more than certain limit. Cylinders must be selected by any of the internationally adopted inspection offices once each two years at least, and it is not permissible to be filled with the gas unless obtaining inspection and test certificates, such as:

- Liquid pressure test
- Air pressure test
- Buckling test.
- Walls or base thickness test

- Valves safety tests.

Evaporators are used when the quantity of the chlorine required being sucked from the cylinder reaches 75 kg/h for transformation of chlorine from liquid to gas by evaporation chamber inside water or oil bath heated by submersed electrical heater. The gas exits from evaporator exit hole to addition devices.

Evaporators are provided with set of control devices, water level and temperature meters or gas and pressure meters, measuring devices to secure the operation and control as well as alarm devices for water level decrease, temperature decrease and thermostat for temperature control and cathode protection device in addition to water supply and filtration connections.

The available evaporator capacities are 75, 120 and 150 kg/hour

4- Ejector

It is a device consists of conical throttle allows to suck the gas from the narrow area at the increase of water velocity as illustrated in Fig (2-29).

When the water flow from A to C, vacuum occurs at point B, where the gas is sucked.

Each device with certain capacity has special design for the ejector according to different manufacturers of the devices.

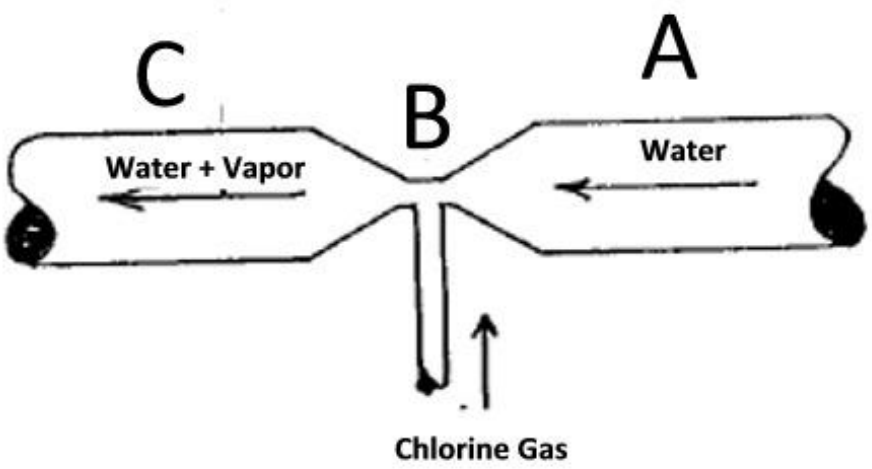


Fig (2-29): Ejector

5- Injection Pumps

They are used when adding (injecting) the chlorine in pipe lines. Pump pressure must = line pressure + 2.5 bar at least to allow easy injection of the solution inside injection points.

Pumps capacity differs according to capacity of installed devices according to the following table:

Chlorine Device Capacity	Pump Minimum Flow
1 kg/h	0.3-0.5 m^3/h
2 kg/h	0.6-0.8 m^3/h
4/5 kg/h	1.5-1.2 m^3/h
10 kg/h	3.0 m^3/h
20 kg/h	6.0 m^3/h
50 kg/h	15.0 m^3/h
75 kg/h	22.0 m^3/h
100 kg/h	30.0 m^3/h
120 kg/h	35.0 m^3/h

6- Injection method in pipes or tanks

This method is illustrated in Fig (2-30)

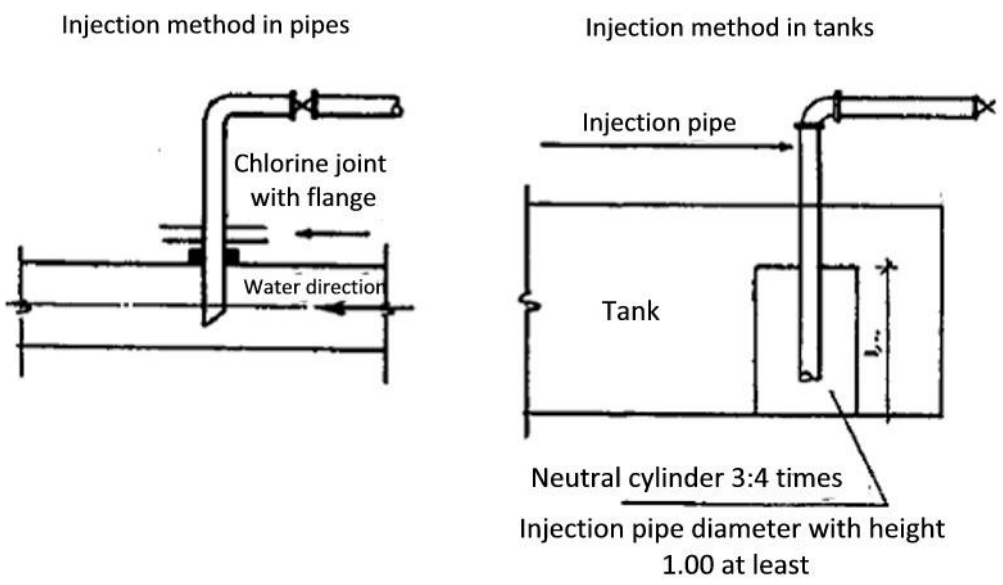


Fig (2-30): Injection Method

Chlorine Stores

Introduction

Chlorine stores are the places for safe keeping of chlorine cylinders. Storage must be in proper way for safety of cylinders, plant buildings and individuals.

Selection of store location:

- There are many conditions for selection of chlorine cylinders stores:
- The store should be adjacent to cylinders operation building, containers or addition devices.
- The store should be near from or at the main street inside the plant for easy transportation and handling.
- The store should be away from fuel stores, workshops, any source of heat or flammable pipes, such as acetylene and oxygen.
- The store should be away from residential complexes, administrative buildings and employees' gatherings.

2-3-2 Store specifications:

- Store should be with suitable area and size to accommodate the cylinders or tanks sufficient for operation of the plant for continuous 10 days in addition to two sets under operation (original and emergency).
- Cylinders must be stored in vertical position for easy access, handling and quick transport.
- Containers must be stored in horizontal position and to prepare turnnions for each container to prevent rolling and for easy turning around their axis.

- Containers should be stored in two or four parallel rows according to plant size and number of handled containers.

- Distance between containers axes should be 120 cm and the space in front and rear of container ends should not less than 1.5m.

- The store should have concrete floor, strong concrete structure and good ventilated concrete ceiling effectively insulated against direct sunlight on cylinders and containers so as ambient temperature inside the store does not exceed 45°C.

- Height of store ceiling from containers store floor should not less than 5.5m.

- Chlorine containers store should be provided with electrical crane not less than 2.5 ton suspended on I shape steel beam size 30 cm at height not less than 5m from store floor and projected 2m out of store entrance to enable handling containers from and to cars board.

- A crane should be used for each row of containers or a crane with circular beam over two rows.

- For small unopened stores, should provide mechanical ventilation equipments (suction fans) with sufficient power to change store air once per 4 minutes at most. Discharge of these suction fans must be directed to neutral chamber through openings and the suction should be near from store floor level.

- All chlorine stores should be provided with alarm devices against chlorine leakage and means for fire prevention (hydrants).

2-3-3 Chlorine gas leakage protection system

Introduction:

- Chlorine cylinders store should be provided with gas leakage protection system and treatment of leakage to ensure safety of workers on the site.

The system consists form the following components:

1. Chlorine concentration measuring system that gives alarm when chlorine concentration reaches 0.3 ppm in store air. Protection system should be operated fully when the concentration is greater than 0.5 ppm through sensors installed in the store and in chlorine devices chamber attached with the store.

2. Protection system (neutralization tower) includes:

2-1 Injection of acoustic soda solution of concentration not less than 10% through special pumps withstand acoustic soda concentration up to 25%. The solution come down from top of neutralization tower through special tower (Fig 2-31) via UPVC pipe or similar with side holes in the form of shower.

2-2 Air suction fans installed inside the store to suck the polluted air and directed it to neutralization tower to meet and react with acoustic soda shower.

3. Ventilation Fans

   They are installed in two groups, one for suction at (0.5-0.7m) from floor level and the other for discharge at 1m from the ceiling to deal with little leakage of gas inside the store or devices chamber.

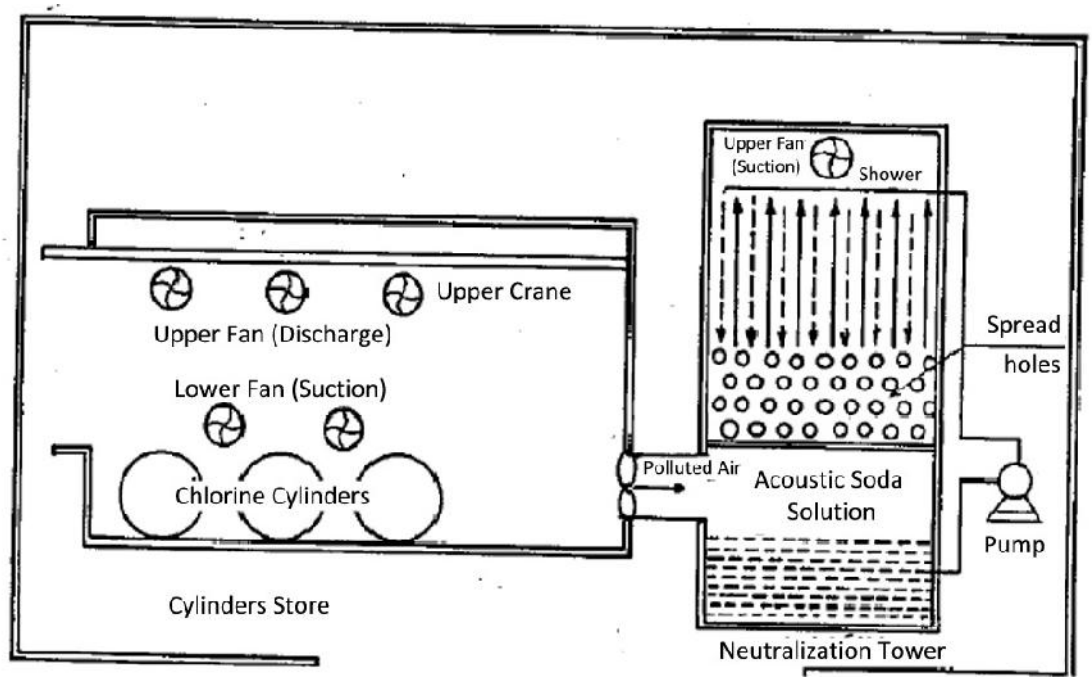


Fig (2-31): Chlorine leakage protection building

Note: All chlorine constructions, whether inside the store or the chamber, should be painted with acids proof paint and upper windows frames should be from wood or aluminum for easy open in emergency cases.

4. Special protective equipments (masks) provided with carbon filters and full face masks for the works provided with air compressed cylinders when handling chlorine devices or cylinders in the store in emergency cases.

2-3-4 Disinfection using ozone

Ozone (O_3) can be used for oxidation of organic materials, water chemical content and disinfection of water from bacteria and viruses instead of chlorine.

It is a gas stronger than chlorine and has great ability for oxidation and disinfection processes and removal of bacteria, algae, iron and manganese in small percentages (0.7 ppm). It is not applied till date in drinking water purification plants or boosters in Egypt because it needs great amount of electrical power (high voltage). It has effective ability for removal of viruses for which chlorine has no effect.

It has also many features and can be extracted from air after being dried from moisture. It cam be also produced directly from oxygen. From the main reasons of not being commonly used in water plants, it does not give constant residue in water, where it is converted directly to oxygen dissolved in water. For this reason, chlorine should be added after it to ensure existence of residue in water as a protection against any potential pollution in the networks and in emergency cases in the tanks.

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 the pumping stations:

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)

η_P = 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.

Definitions of these equipments are as follows:

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 1 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 (3-1) 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 (3-1): 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	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 10,000 connection and

			achieved without maintenance.	disconnection processes.

Table (3-1): Comparison between types of H.V Circuit Breakers

Table (3-1): 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
		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 fire walls (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.		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.	

Table (3-1): 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.

Table (3-1): 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 (3-1): 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 (3-1): 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-t-CO-t-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 (3-3) 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 (3-2): 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 (3-3): 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 A cb used or tested under installation conditions may have connections the type, hature 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 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.

3-2-5 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.

3-2-6 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 (3-4) 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 (3-4): 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 (2-7) 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 (3-6) and Table (3-7) 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.

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

Table (3-5): Comparison between electric losses in some types of transformers (1000 KVA)

Table (2-6): 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.

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.

Table (3-7): Temperature-rise limits in oil 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. 20°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 (3-8) 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 3-1).

Table (3-8): 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	+	+	1.93	1.83	1.69	1.00
t = 1	1.89	1.80	1.70	1.62	1.50	1.00
t = 2	1.59	1.53	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

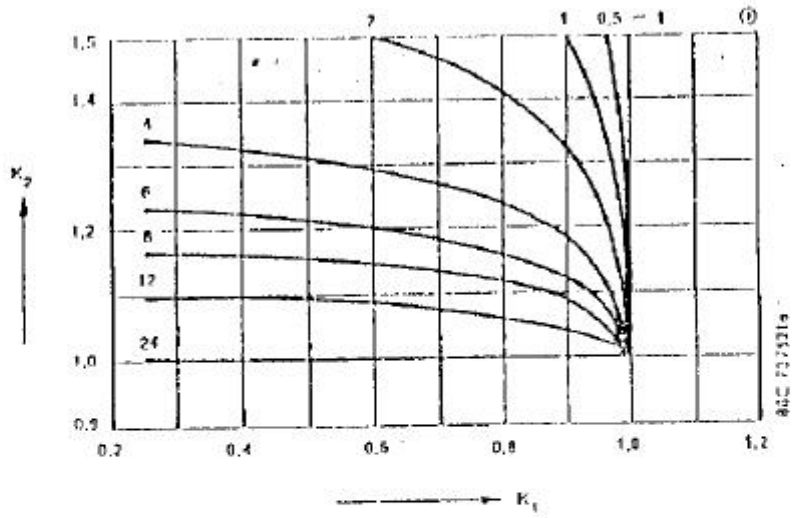
Dry and immersed transformers (except mineral oils) are considered fire proof, this does not mean these materials are non-inflammable although these materials have fire point (is the temperature at which occurs continuous burning of the material when subjects to flam at its surface). The most important 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 (3-9) 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 (3-10) 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 (3-1): Relation between K1 and K2 at different values of loading period t

Table (3-9): Fire point for some fire proof materials

Material*	Fire point (°C)
Silicone liquid	360
Nidel 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.

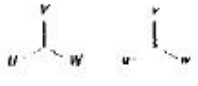
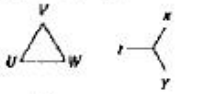
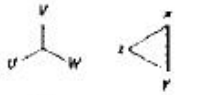
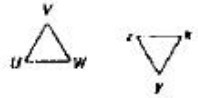
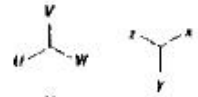
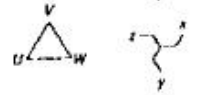
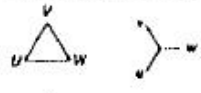
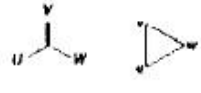
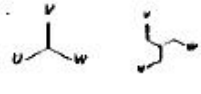
Table (3-10): Removal Heat Rate (RHR) values for some fire proof materials

Material	RHR	
	convective (kW/m)	radiative (kW/m)
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 (2-3) 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.

Designation Clock hour figure	Vector group ①	Vector diagram HV	Vector diagram LV	Wiring diagram ② HV	Wiring diagram ② LV
0	Dd0				
	Yy0				
	Dz0				
5	Dy5				
	Yd5				
	Yz5				
6	Dd6				
	Yy6				
	Dz6				
11	Dy11				
	Yd11				
	Yz11				

① If the neutral is brought out, the letter "N" must be added following the symbol for the h.v. winding, or "n" following that of the l.v. winding; e.g. l.v. neutral brought out = Yyn0.

② It is assumed that windings are wound in the same sense.

Fig (3-2): 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 (3-11) 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 (3-11): 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:

$$A = 0.06\ P$$

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 (3-3) shows nomogram for determination of areas of air inlet and outlet.

Fig (3-4) 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.

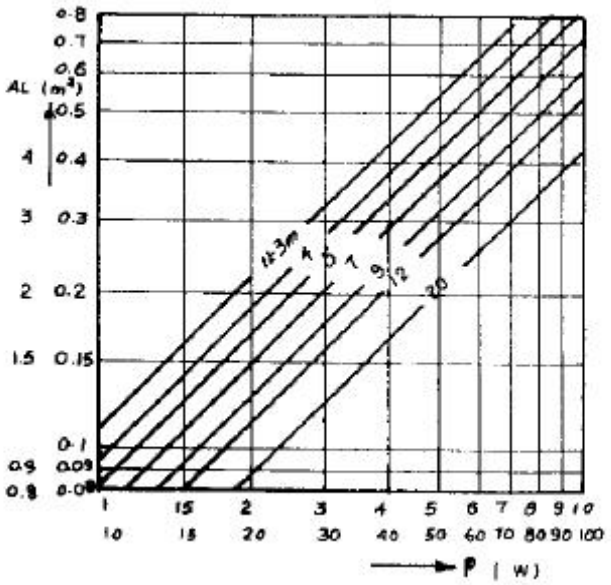
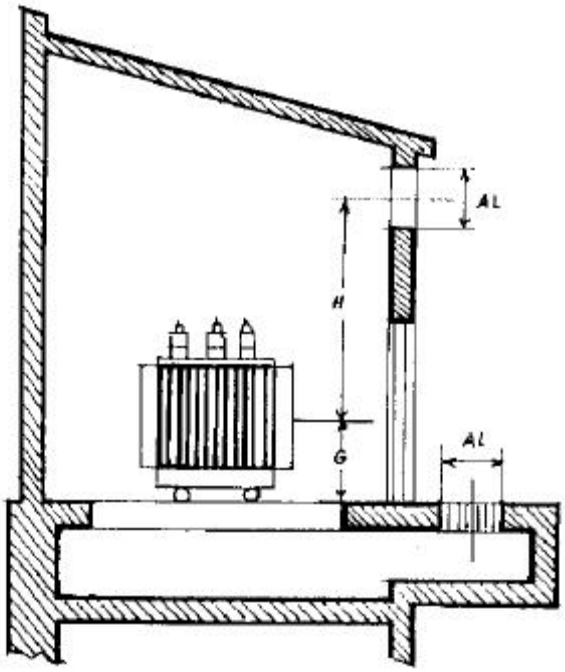


Fig (3-3): Nomogram for determination of areas of air inlet and outlet



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 (3-4): 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 $\pm$ 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,

$$\frac{W}{t} = I^2 R \quad \text{---------- (1)}$$

$\frac{W}{t}$ = 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:

$$\theta = \frac{W}{t} \quad \text{---------- (2)}$$

Where:

θ = Heat flow per second

* By applying Ohm's Law, the heat flow is calculated as follows:

$$\theta = \frac{\Delta T}{Rth} \quad \text{---------- (3)}$$

Where:

R_{th} = Thermal resistance of the conductor (thermal ohm) and is calculated in °C/Watt

The thermal resistance consists of internal thermal resistance (R_{thi}) from the conductor to the outer surface of the cable and external thermal resistance (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 (3-12) shows current ratings for copper cables laid in air with P.V.C insulated conductors.

* Table (3-13) shows current ratings for copper cables laid in the ground with P.V.C insulated conductors.

* Table (3-14) shows current ratings for copper cables laid in air with XPLE insulated conductors.

* Table (3-15) shows current ratings for copper cables laid in the ground with XPLE insulated conductors.

* Table (3-16) 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 (3-12) 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 (3-13) 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
mm²	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	280
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	985	900	—	—	615	500
500	1130	1000	—	—	—	—
625	1300	—	—	—	—	—
800	1500	—	—	—	—	—
1000	1700	—	—	—	—	—

Table (3-14) Current ratings for copper cables laid in air with XPLE insulated conductors

Current ratings and protection for cables laid in air with (cross-linked polyethylene) insulated conductors.

Nominal cross sectional area of copper conductor mm²	Single-core cables*		Twin-core cables		Three- and four-core cables	
	Current rating A	Highest nominal value of the fuse A	Current rating A	Highest nominal value of the fuse A	Current rating A	Highest nominal value of the fuse 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 (3-15) 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 mm²	Single-core cables[2])		Twin-core cables		Three- and four-core cables	
	Current rating A	Highest nominal value of the fuse A	Current rating A	Highest nominal value of the fuse A	Current rating A	Highest nominal value of the fuse 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 (3-16) 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 (3-17) 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 (3-17) 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 cores 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	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	and	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	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

$$\Delta U = 2.I.l \frac{r}{1000}$$

Where:

ΔU 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

$$\Delta U = 2.I.l. \frac{r \cos\phi}{1000}$$

ΔU 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

$$\Delta U = \sqrt{3}\, I.l \frac{r \cos\phi}{1000}$$

Where:

ΔU 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

Cos φ = 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

$$\Delta U = 2.I.l. \frac{r\cos\phi+\chi\sin\phi}{1000}$$

(2) For three phase AC

$$\Delta U = \sqrt{3}.I.l. \frac{r\cos\phi+\chi\sin\phi}{1000}$$

Where:

χ is cable impedance in ohm/km

Can be taken 0.1 ohm/km

* The nomograms shown in Fig (2-40) and Fig (2-41) 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

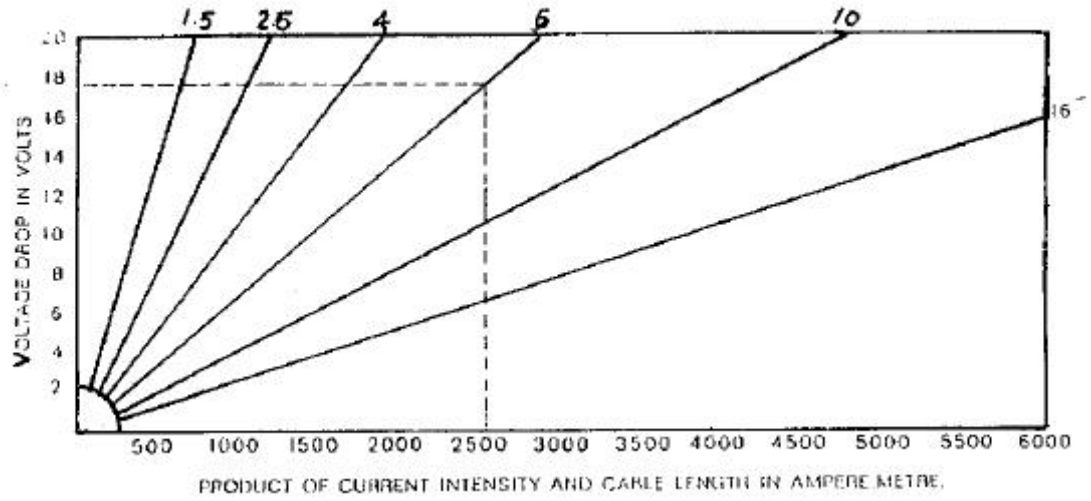


Fig (3-5): Nomogram for calculation of voltage drop for double cores cable, single phase alternating current, Cos $\varphi = 1.0$

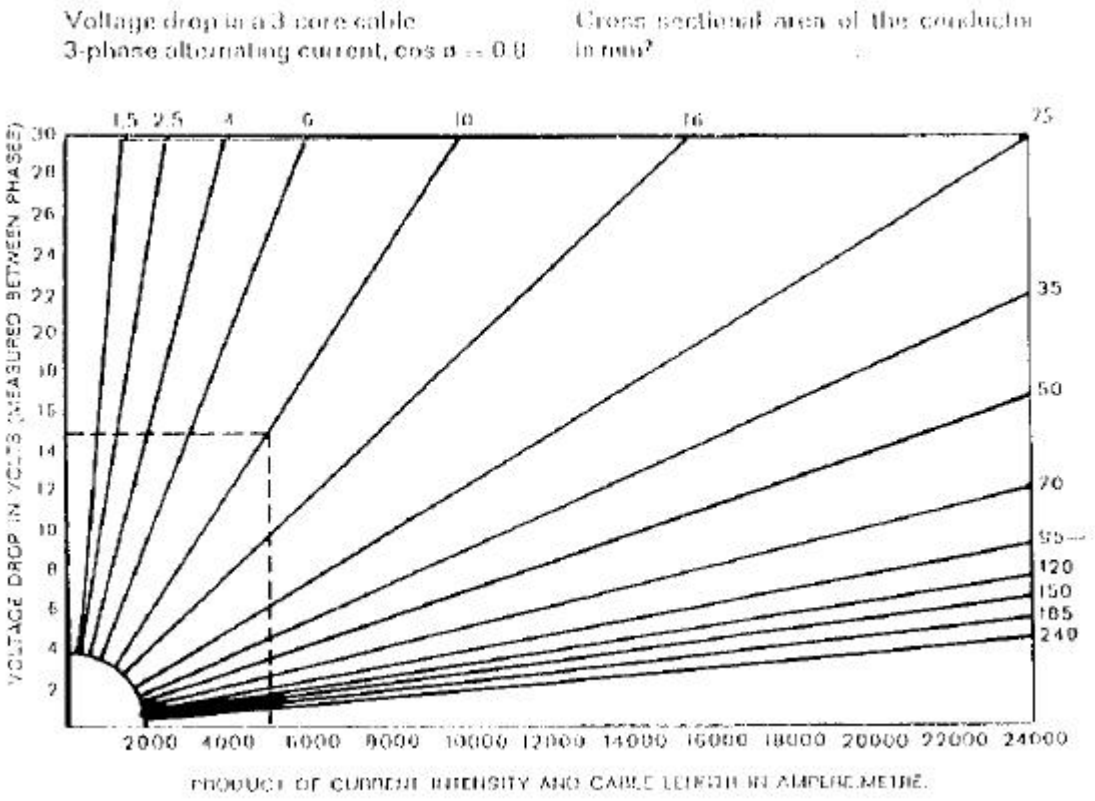


Fig (3-6): Nomogram for calculation of voltage drop for 3- core cable, 3- phase alternating current, Cos $\varphi = 0.8$

q = Nominal cross section area of the copper conductor in mm^2

This formula is applicable for temperature rise between (70-150) °C

Fig (3-7) 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:

$$Ik = \frac{\sqrt{t}}{144} \cdot q$$

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 (3-8) 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.

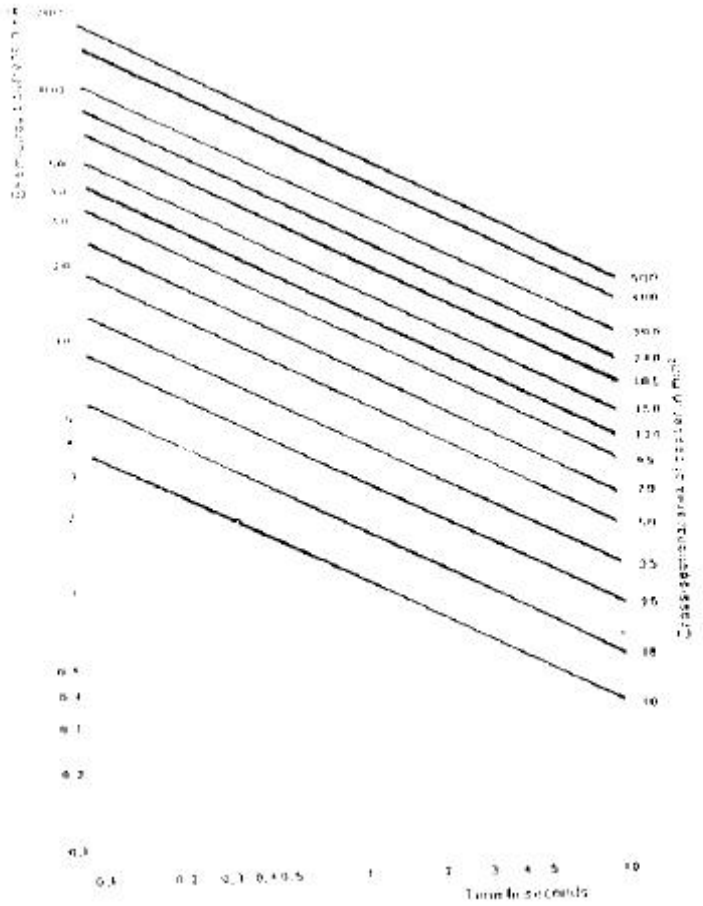


Fig (3-7) Nomogram the relation between the short circuit, time and the cross section area of the cables with PVC insulted conductors (LV copper conductor cables)

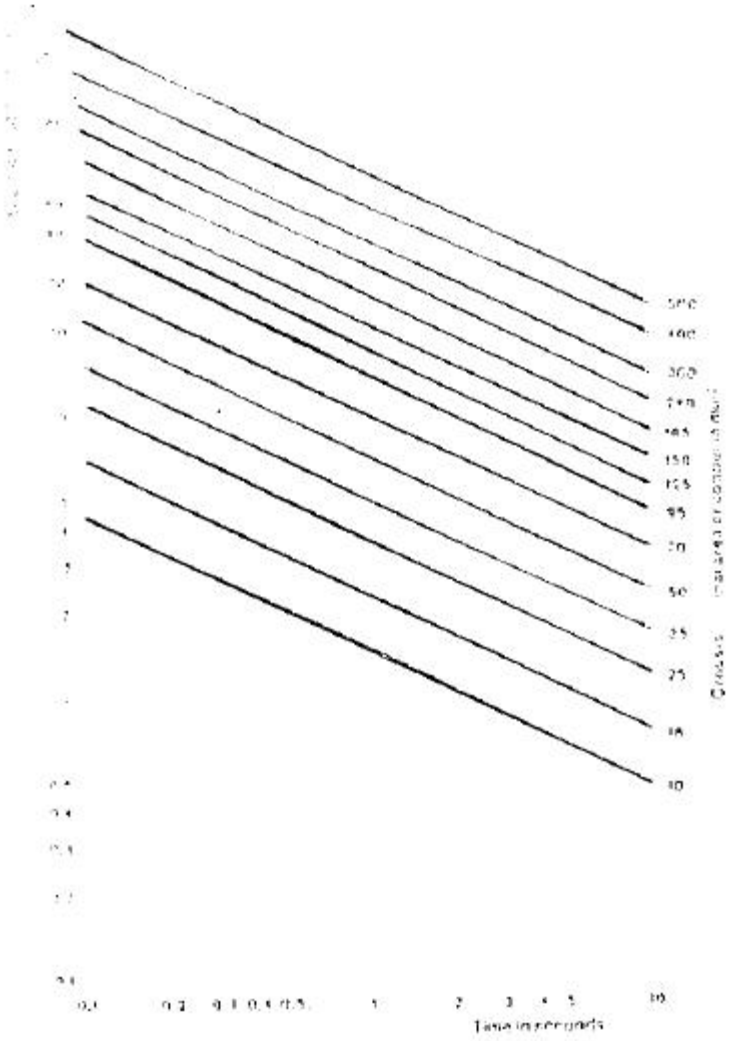


Fig (3-8) Nomogram the relation between the short circuit, time and the cross section area of the cables with XLPE insulted conductors (LV copper conductor cables)

3-5 Electrical Power Generation Station

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.

3-5-1 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.

3-5-2 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.

3-5-3 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

3-5-4 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.

3-5-5 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.

3-5-6 Starting Systems

The generator motor is started by one of the following two methods:

- Electrically (battery + starter motor).
- 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.

- ARCHITECTURAL AND CONSTRUCTION DESIGN

4 – 1 Architectural Works:-

4 – 1 – 1 General Layout:-

Units shall be distributed on the site layout of the boosters in a way that allows the provision of the following elements:

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 to be connected with the buildings that will be built there (its width shall be not less than 4.0 m beside the pavements).
2. The rooms for the guard and reception shall be adjacent the main entrance of the booster.
3. There shall be green areas among the units.
4. Building residential buildings for workers in posters that are located in distant areas away from the posters units. It is preferred to have an independent entrance together with studying the wind direction so as to avoid being subjected to gases in case of chlorine leak.
5. The site shall be provided with the networks of feeding, irrigation, sewerage, electricity, lighting, communications and fire fighting.
6. There shall be car parking.
7. A suitable fence shall be made to secure the site.

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 Motors house:

- The floor height of the storehouse for administrating the motors shall be at a suitable height of the road level.
- The electricity connection from its sources shall be easy, paying attention to the economic aspects.
- The distance between the winch beam and the lining of the ceiling beam shall be suitable; in a way that does not impede the safe operation.
  - The ventilation and lightening inside the unit shall be taken into account.
  - Taking into account the existence of banisters around holes.
  - The sewers of the cables shall be plunged under the ground and covered with covers with levels equals the level of the ground of the storehouse, having movable handles.
  - The floor of the pump storehouses shall be made of antacid, antifriction ceramics; the walls shall be made of faience with the suitable height – taking into account the existence of suitable holes for the renewal of air inside the storehouse.

4 – 1 -2 -2 Transformer and Generator House:

- The dimensions of the building shall be identical with the specifications of the authorities and companies of the ministry of electricity.

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- There shall be doors for the generators building for the outside fence and for one of the main or sub roads to be accessible.
- The distance between the winch beam and the lowest point in the ceiling beam shall be suitable; in a way that does not impede the safe operation.
- The ventilation and lightening inside the unit shall be taken into account.
- The interior finishes shall be made of materials that are suitable for the building. The floors shall be made of antacid, antifriction and not sliding ceramics, the covers of the sewers of the cables shall be made with levels equals the level of the ground of the storehouse, having movable handles.

4-1-2-3 Workshops and stores:

- The distance between the winch beam and the lowest point in the ceiling beam shall be suitable; in a way that does not impede the safe operation.
- The ventilation and lightening inside the unit shall be taken into account.
- The entering and exiting of cars, equipments and machines to and from the entrance of workshops and storehouses shall be easy.
- They shall be as close as possible from the rooms of taking off clothes.
- The internal finishes shall be made of materials that are suitable for the building. The floors shall be made of not sliding ceramics; the sewers of the cables shall be made with levels equals the level of the ground of the storehouse, having movable handles.

4-1-2- 4 Chlorine and chemicals building:

- The entering and exiting of cars containing supplies, chlorine cylinders and maintenance tools.

- The finishes materials that are anti chemicals shall be used in making the floors of antacid ceramics and walls of faience with the suitable height not lower than the windows frame.
- The iron bases carrying the cylinders shall have four rotary rollers (iron wheels) for each cylinder. The basses shall be at the distance of not less than 1.0 m away from the side walls so as to make the movement easy and adjusting the position of the cylinders and locks for the correct method of operation.
- It is preferable to make an upper winch (monorail) with a suitable distance between the winch beam and the lowest point in the building beam for every cylinders group, with the beams falling in the entrance of the Chlorine building not contradicting with the path of the winch beam and with the suitable height so as to make the handling of cylinder easy from the cars' surface.
- The winch beam shall extend outside the building for a distance that is enough for allowing the safe loading and discharge.
- The pump network of Sodium Hydroxide relating to neutralization shall have a good design so as to make checking up them periodically.
- Cement sewerages shall be made with easily lifted covers for the chlorine injection pumps, which are made of PVC or a similar type, to pass along.
- The ventilation openings shall be with the height of more than 50 cm from the ground of the chlorine building, with an opening of not less than 35 × 35 cm; the distance between each two openings shall not exceed 2.0 meters.

- In case of having a chamber for the neutralization of the leaked chlorine gas, the door opening shall be from the backward outside the storehouse, the height of aspirators in this chamber shall be in the side of the cylinders storehouse at the same level of the locks of operating the working cylinders.
- Suitable lighting and ventilation for the building shall be available, together with the sewerages for draining the washing water.
- The following conditions shall be applied to the base of the neutralization tower:
- The base relating to the fixation of the neutralization tower shall be with the height of not less than 2.0 meters from the ground of the chlorine building.
- The interior walls shall be treated with antacid materials.
- The upper opening relating to the fixation of the neutralization tower shall be lined with rubbery material (rubber) and such rubbery material shall be preventing the leakage of air.

4-1-2-5 Administration and laboratory building:

- It shall be close to the main entrance of the station so as to control the work and workers easily, access the rest of different buildings, and facilitate the sampling process either manually or using pumps and special equipments.
- The wind direction shall be studied so as to avoid exposing the building to any leaked gases; the laboratory shall be provided with a special system for discharging gases.
- The enough ventilation and lightening inside the unit shall be available.
- The finishing materials for grounds shall be of antacid, anti friction ceramics, and walls of faience.

-

- Upper side openings shall be made for installing aspirators for driving the gases vapors out; the level of such openings shall be less than the level of the laboratory roof with enough distance.
- The sanitary connections relating to basins (water – sewerage), which fit the laboratory shall be provided.
- The surfaces of the laboratory tables shall be coated with the natural marble, ceramics, or the equivalent.
- It is preferable to have the laboratory in the ground floor, in case of constructing it with the administration building. It also shall have a separate entrance and shall be divided into a number of subsidiary laboratories like chemical, bacteriological, biological, and physical laboratories together with a washing room, scales room, chemists and supervisors offices.

4-2 Construction Works:

Refer to Egyptian Codes concerning construction works.

5- Preparation of Tender Documents

5 – 1 INTRODUCTION:

The tender documents to be released include the technical information about the project, and general as well as special conditions, which are considered to be the arbitrator to which each party in contracting shall refer and upon which they depend if necessary.

5-2 Components of tender documents

The tender documents consist of the following volumes:

- the book of general, special conditions as well as the 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

- The volume shall contain the following:

(A) Invitation to tender

(B) Tender form

(C) Instruction for the bidders

(A) Invitation To Tender

The invitation to tender will be in a page or two pages with a brief description about the project and the procedures related to the tender. Such invitation shall include the way by which one can get a copy of the tender documents, its pricing, date, and place of such documents delivery. Such tender shall be advertised in the daily newspapers (two wide spread newspapers) for two consecutive days.

(B) Tender form

The tender form determines standard format for the contractors to submit their prices and offers to the employer; this will facilitate the technical and pricing comparison for the equality of opportunities between them.

(C) Instructions For The 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
- Security deposit & Guarantee deposit
- Contraction form between the owner & contractor
- Additional instructions

5 – 3 Insurance Forms

The tender documents include forms for the formula of the security deposit to be submitted together with the tender and the guarantee deposit, to be submitted by the contractor who wins the tender, from an authorized bank. The formula stipulates that the employer shall have the right of making use of this deposit for his own favor by the first bank notice about this. Any objection on the part of the contractor shall not be taken into account. It is necessary for this deposit to continue to cope with its purpose.

5 – 4 Contract between the Owner and the Contractor

Such contracting is so important that it is considered to be an independent document. This contracting includes five main principles, which are the following:

- The similarity and identification between those who signed on this contract legally, the legal capacity of the signed concerning executing it, and signing a number of the original copies shall be enough for having an original copy for the owner, contractor, supervising engineer (if any), contracts & purchases and the state council.
- A brief, clear description for the project.

- The expected execution time for finishing is very important as it may result in delay fines, contract extension or the like.
- The price, either the full fixed price for the project as a whole, the price for each article of the work articles, or the unit price for every group of similar articles for works according to the agreement.
- The payment terms through the periodical billings according to progressing works as well as the deduction of certain percentage to be accumulated till the primary submittal together with what is deducted out of the percent of the advanced payment of the contractor, etc.

In addition, the system of the final statement for the process which is considered to be one of the legal statements in the project period.

This contract includes the relationship between this document and the rest of documents of the tender; this is for the legal capacity as this is the only document signed by the contract parties.

5 – 5 CONTRACT CONDITIONS:

The contract conditions are divided into two types: general terms and special; complementary terms.

5 – 5 – 1 GENERAL CONDITIONS

The general conditions include the rights and obligations of both the owner and the contractor. It also explains the frame of works under the responsibilities the consultant engineer supervising the execution (if any) as well as the works and the responsibilities of the project manager.

The most important terms included in these general conditions include:

A. Definitions

The important terms like the following shall be defined clearly and accurately:

The owner (consultant engineer – project manager) – the contractor – the subcontractor – the supervising engineer – the work – the project – the tender documents – the drawings album – start date of project execution – end date of project date.

B. Rights & Responsibilities

The rights and responsibilities of every party shall be defined for each party in detail. This is to be done to help each party understand the limit of his rights and responsibilities concerning the contract. In addition, it shall define the relations with the subcontractors to whom the main contractor has given his rights and responsibilities.

C. Subcontracting

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 set for dealing with the ways of settling disputes resulting from work in detail whether amicably or by arbitration.

E. Duration:

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- Statements & 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.

- Procedures of (Temporal) Preliminary and Final Handover

(A) (Temporal) Preliminary Handover

- 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 of work 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.

(B) 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.
- 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.

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.

(Fourth volume: Boosters)

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 part of the works is 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 preparation
3. Implementation of Civil and architectural works
4. Implementation of Mechanical and Electrical Works
5. Implementation of Electrical Works
6. Tests
7. Performance Tests and Handing Over

1- Project Implementation Management

Success in any project is to be measured through finishing it on time according to the documents of contract, terms, technical specifications and the shop drawings.

The key to success in the project is having means of communication and understanding among parties working in the project; this is to be achieved by having a communication among the project owner, the consultant and the contractor. This would help in executing the works according to the specified schedules for finishing this project.

The work force necessary for finishing the works depends on the size as well as the status of every project. The figure (1-1) shows the organization of the project administration.

For the good coordination among the three parties, the following organization shall be followed:

A. The project owner shall enter into contract with the contractor to whom the execution of the project is assigned according to the applicable regulations and laws.

B. The project owner shall form an executive body for the purpose of the technical review for all the execution steps, defining the blocks and problems facing the project, working on solving them either they are technical, financial, managerial, or legal.

C. The executive body shall coordinate with the project consultant who made studies, designs, and prepared documents for supervising the execution.

D. A chief for the executive body shall be appointed (the project manager) to coordinate between the work team in the unit and setting the work relation between the executive unit and the consultant.

E. The project manager shall coordinate the works of the owner, the contractor and the consultant; figure (1 – 2) shows the project executive body with the following duties:

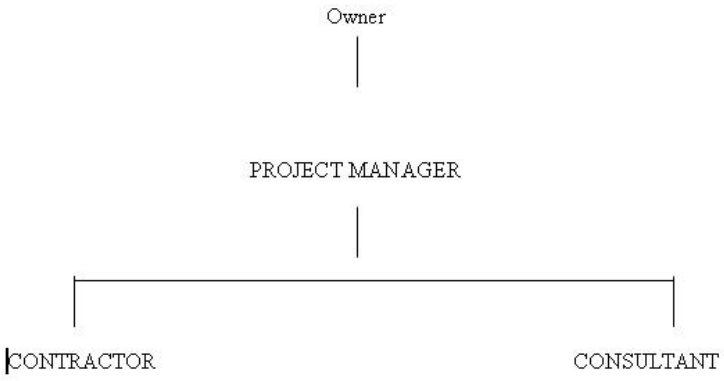

Figure (1 – 1): Organization of the Project Management

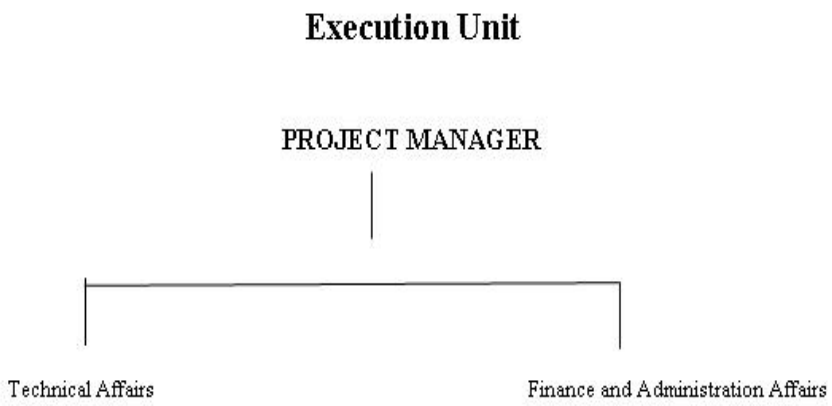

Figure (1 –2): Formation of the Project Execution Body

1 – 1 Project Manager

(A) He shall have the efficiency as well as the abilities for managing the project;

(B) He shall be responsible for following up the consultant engineer supervising the execution of all the works and all the related activities (if any). He, the project manager shall have the right of monitoring and coordinating between different activities either they are technical, financial, managerial, or legal; he shall be aware of them.

(C) He, the project manager may choose the best way for executing the works in cooperation with the consultant supervising the execution (if any). He shall consider in his choice the economical aspects, time and effort so s to achieve the goal of finishing the project on its due date. In addition, he shall take the necessary actions that endure the correction of the execution progress so as to finish 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 Implementation 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 Auditing

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 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 (1-3) 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.

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.

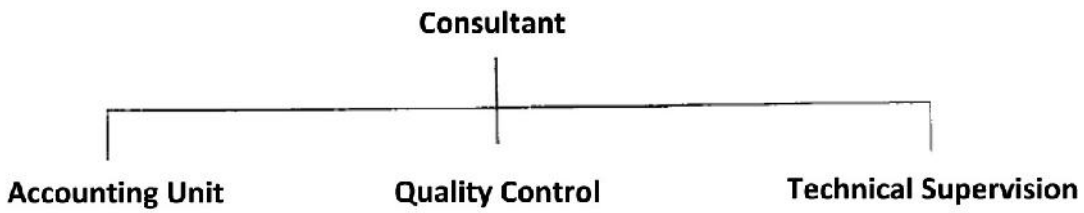

Fig (1-3): Organizational Structure of the Consultant

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 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 (1-4) shows organizational structure of the contractor.

1-6 Resident Engineer

He is responsible for 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:

1-6-1-1 Technical revision

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 or owner's representative.

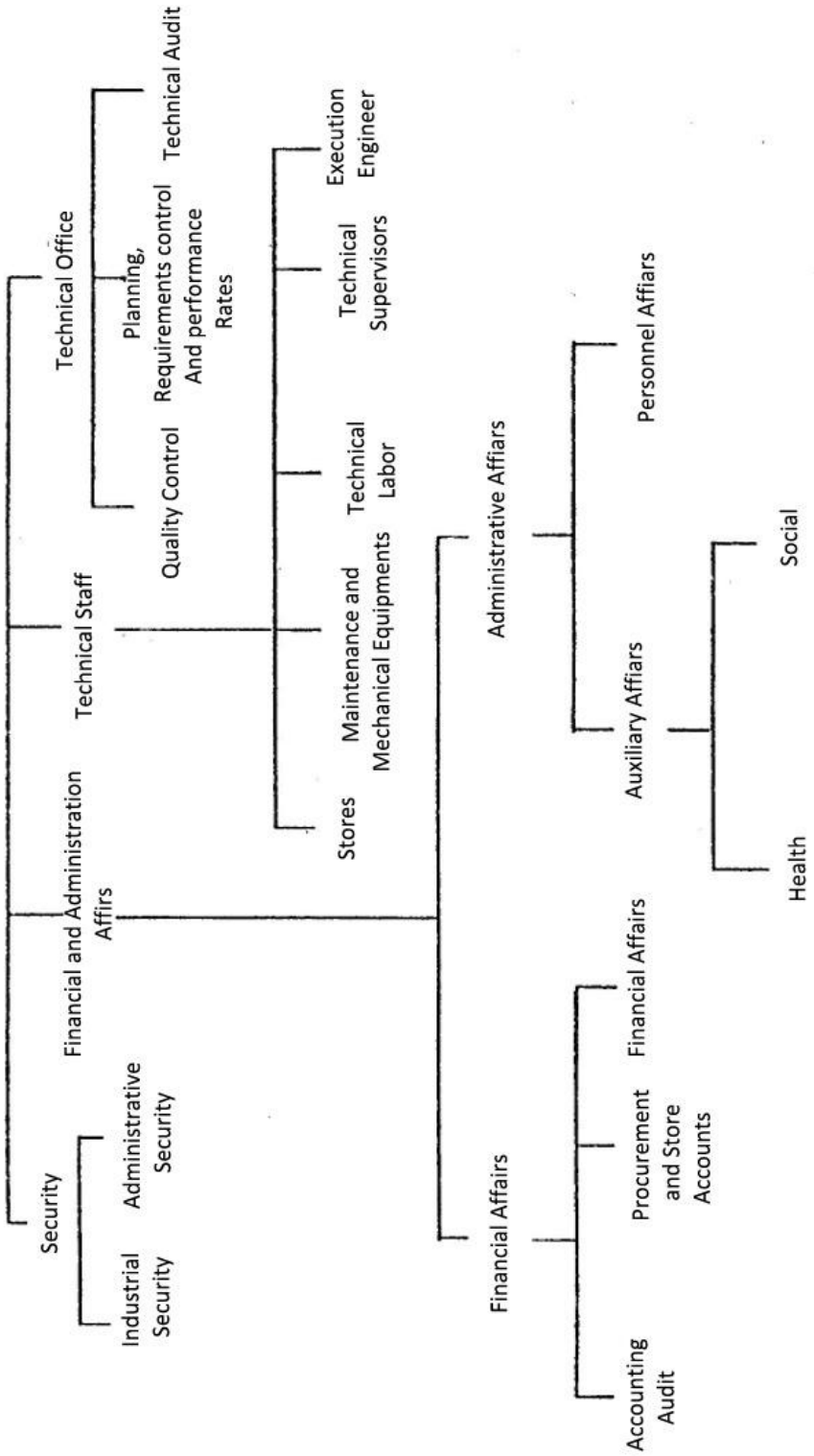

Figure (1-4): Organizational Structure of Contractor

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, follow up, procurements and performance rates

It is responsible for 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 Implementation 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 workers

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 technical vehicles

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 reaches to the critical limit.

1-6-3 Financial and Administrative Affairs

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

2 – 1 planning works:

The success in any project is measured through determining the period enough for planning and applying the implementation basics in terms of the following:

A – Finishing the procedures of dispossession of lands specified for implementation and having the finance enough for them;

B – Inspection and soil testing

C – Preplanning for finishing the project on time through following the procedures necessary for the project execution

D – Therefore, the best way to reach the desired goal starts from good planning and analysis of project components to the executive steps.

Planning works are as follows:

2-1-1 Determination and handover the site

A. Takeover the allocated area of the lines path, pump location and the ground tank from a committee consists of the owner, the consultant, the contractor, representative of the beneficiary body of the project.
B. Determine the lines path specified for the project construction as well as the location of the pump and ground tank by putting iron fence around the site by representative of survey department.
C. Put a fence around the site of pumps and ground tank, construct a gate for entrance and exit of equipments as well as security and information office.

2-1-2 Survey works and borings inspection

A – Constructing a constant bench mark for the site related to the nearest authorized bench mark.

B – Making a grid and linear budget for the site and the pipes lines.

C – Planning for the site of pumps and ground tank, determining places of units, revising soil and foundations research reports to detect the nature of the soil and foundation depth; this to determine the equipments necessary for borings, breaking, supporting borings side, draining shallow as well as ground water, and preparing the raw materials to be used in implementation.

2-1-3 Determination of units' locations.

The locations of units and sub-bench marks shall be planned for and determined using iron fence fixed on the external borders of the unit with the constant bench mark, in presence of the consultant and the owner representative.

2 – 2 preparation works:

They include the following:

2-2-1 Stores and determination of storage areas

A- Construct temporal stores under the necessary dimensions and specifications in places where no units are expected to be built so as to store materials, instruments and equipments necessary for implementation to keep them away from loss, damage, and weather conditions. Such storages shall be put into the storages after being inspected technically under the store procedures that specify the class, type, date of entrance and usage during the implementation period using support and exit permissions for these storages.

B- Determine storage places in a medium place among units (where no units are expected to be built) so as to reduce the handling costs as well as depreciation percent, in case of necessity, storage sites shall be set in places specified for units deferred till the end of the project.

2 – 2 – 2 workshops

Small temporal equipped workshops shall be constructed for maintenance of equipments and vehicles serving the project.

2-2-3 Employees offices

Temporal units shall be constructed as offices for workers to serve as follows:

(resident engineer – technical office – execution engineers – stores – accounting unit – safe – personnel affairs – security – buffet – water closets – prayer's place – switch & wireless room)

2-2-4 Employees rest room

Rest houses shall be constructed for the site workers, if the site area allows this or renting residential units near the site. The workers who shall be resident at such rest houses are those who are not from the city where the project is to be built. The rest houses shall be equipped with all the conveniences like furniture, kitchens, water closets, etc.

2-2-5 Transportation means

Provide cars for workers of the project to convey them from their gathering point to the work site.

2-2-6 Sources of water, electricity and telephone

Provide sources of water necessary for the feeding and implementation of works, electricity necessary for operation and lighting and means of communication either through wireless set or telephone.

2-2-7 Roads paving

A – The road leading to entering into the site to facilitate entrance and exit of equipments shall be paved.

B - Internal roads in the site shall be paved so as to facilitate the easiness of equipments motion inside the site and keep them.

C – A road is to be constructed (if necessary) to connect the site to one of the main roads.

2–2–8 Implementation Equipments:

A – Equipments necessary for work implementation shall be detected according to the implementation schedule.

B – A schedule for exit and entrance of equipments shall be made upon the need of work.

C – A maintenance program shall be made for equipments to keep their operation efficiency.

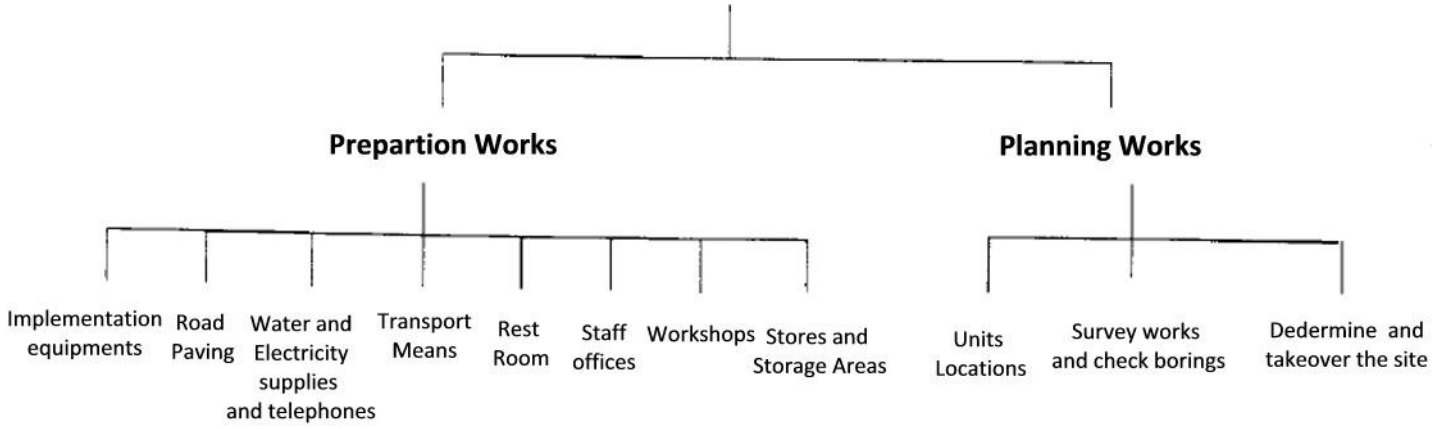

Fig (1-5): Site Planning and Preparation

3- Civil and architectural works implementation

Introduction:

By the order of implementing the pump civil and architecture works, all what is stated in the Egyptian codes related to conditions of implementing the reinforced concrete, soil mechanics, foundations, pipes, etc. shall be taken into account.

The pumps include the following:

- Water tank
- Pump station
- Services building

3-1 Conditions of civil and architectural works implementation

3-1-1 General layout

1 – Site handover

2 – Construct a fence for the site and preparing it with security procedures

3 – Prepare offices for the supervision staff in the site including supporting them with necessary connections like water, electricity, communications services, etc.

4 – Revising the survey works according to the drawings as well as fixing the supporting survey bench marks in fixed, clear places inside the site.

5 – Determine entrances and exits and implement temporal internal roads leading to the site

6 – Determine places of stores so as not to contradict with works of implementing the project units

7 – The execution engineer shall refer to the designer, in case of getting a difference between borings made by the contractor and previous borings report to get his opinion.

8 – Be acquainted with the implementation documents and setting the priorities of implementation according to the foundation levels and the detailed schedule.

9 – Provide the site with necessary storages including materials, raw materials and equipments necessary for construction following the technical standards of storage and comparing these supported materials, either natural or manufactured as well as equipments of different types to the samples and authorized specifications.

10 – Form a standard concrete mixing from the storages in the site and determine the opposite mixing for the largest required break according to the executive drawings.

11 – Have axes and units' locations identical to the nature according to the executive drawings.

12 – Achieve sequence and technical coordination in implementing the related works (civil and architecture works, mechanical and electrical works) allowing for any contradiction or difference among them according to the schedule.

13 – perform the works of foundations excavation, casting concrete, and controlling the ground water level (if any) through following up its levels daily during the observation days and recording them, revise the levels of low water surfaces during the work implementation, in case of any unexpected fall in such levels, please refer to the designer to take the suitable actions so as to avoid any impacts or risks resulting from this.

14 – Prepare and perform the final drawings (according to executor) of the layout after having finished the units' implementation that prove to be valid according to as built drawings.

15 – The following points shall be taken into account

A- Giving the priority to the treatment of the places of aperture;

B- Using shuttering so as to get a concrete fair face surface from inside;

C- Making sure of the places and way of working of the water stop keeping them during casting so as not to damage them or replace their places;

D- Taking into consideration the cleaning of the casting bars in case of being stated in the executive drawings, and dealing with them according to what is stated with the Egyptian code of the cement

16 – Following up the executive program and drawing the contractor's attention to any delay or a work not following the specifications for preventing the delay of work so as to continue in work according to the executive schedule. In order to maintain the lifelong of the water cement buildings, they shall be isolated in the following way:

A- Interior isolation only if the building is higher than the level of ground water.

B- Interior and exterior isolation in case of having a building that equals the limits of the ground water level.

3 – 1 – 2 - pumping stations:

The following points shall be taken into account:-

A- In case of having the booster design including pumps installation to embody the future expansions, these bases shall be executed for the pumps.

B- Checking the fixture of anchors of pump chassis before casting the reinforced concrete according to the mechanical drawings.

C- Executing the inclinations in pump store house floor as well as the cable trenches to facilitate discharge of any water get cumulated in the store house or such trenches and their way of discharge.

D- Leave places for wall openings to install the pulling and discharge pipes during the casting of the reinforced concrete together with cables trenches and lighting pipes.

E- An area of not less than one and half of the width of back leaf of the electricity board or of not less than 1 meter according to which is greater; this is in case of boards with back doors.

F- The upper winch has to serve all the sets of pumps, either recent or future.

Administrative units, workshops, external fence, guarding towers, guardian room

- As for the Administrative units and services (Administrative building, fence, security, workshop, store, …), they are according to what is stated in the Egyptian Codes.

4- Mechanical works

4 – 1 General Conditions

By the execution of the mechanical and electrical works for the purification stations, the following points shall be taken into consideration:

4-1-1 Before equipments installation

A- The implemented civil works shall be reviewed to make sure of the designing dimensions existing in the executing drawings, levels, miles and the all the elements of the civil finishes mentioned in the drawings and specifications related to these works.

B- The dimensions and axes of the openings as well as their levels shall all be reviewed together with the requirements necessary for installing the mechanical equipments through these openings according to the executive detailed drawings of the mechanical works.

C- The mechanical equipments as a quantity and quality shall be reviewed as well as comparing them with the supply order in terms of model, serial numbers, origin certificate, and inspection and test certificates making sure of the elements and parts of equipment comparing it to the list of contents and mechanical detailed drawing.

D- The equipments shall be checked from outside to make sure that there is no break or damage resulting during the transportation process.

4 – 1 – 2 – During Installation:

A- Set steps for the installation of equipments considering the arrangement of the equipments installation with each other, the installation works start with the crane equipments (winches), then the compound equipments in the lower levels then the upper levels and in this way,; this is shall be reviewed with the instructions set in the instruction manual of supporters and manufactures

B- Adjust the axes and levels of the equipment before insulation over the special basics and setting connections among equipments.

C- Make sure of valves installation in terms of the direction of the locking and opening, arrangement of their position and directions (direction of the arrow on the valve).

D- Check all the parts need to be lubricated and use the lubrications according to the manufacture instructions.

E- Inspect the electrical connections among mechanical equipments and control as well as operation panels.

4 – 1 – 3 After installation: -

- After finishing the installation works and before starting operation, each equipment shall be operated for a very short period of time to make sure of the rotation direction.
- Make trials of tests in the site according to the tests part.
- The operation period for performance trials that shall be not less than 72 hrs with no stop, in case of success with no problems or obstacles, a minute of preliminary handover shall be executed and the insurance period for such equipments starts from this date.

4-2 Conditions of mechanical works installation

4-1 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 Generators

- Before installation of the generators, must ensure at first, fitness of the generators after shipment and transportation to the site and non-existence of breaks or cracks on the generators body or any defects in any part thereof.
- Must conform the data listed on the data tag of the generators to the data and specifications stipulated in the contract.
- It is necessary to obtain full information about correct installation of the generators, including all details of the pipes, corresponding water levels, maximum and minimum operating conditions from generators manufacturer manual.
- Generators 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.

5 - Electrical works implementation

5 -1- Electrical motors

- 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.

5-1-2 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.

5-1-2 Starting 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.

5-2 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.

5-3 Cables

- Method of cables installation depends on the place that will be laid on taking into account that the shortest path is not the most economic one. Soil nature has direct effect whether it is rocky or aggressive.

- Method of installation of mains cables are:

- Direct buried in the ground.

- Withdrawn inside ducts buried in the ground.

- Laid inside troughs

- Air installation on cable holders and cable trays or on the ascending or descending ladders.

- Direct burying in the ground leads to high cost of excavation and the cables should buried at sufficient depth to avoid damage of the cable from the surrounding conditions. Soil around the cable must not contain any rocks with sharp edges or any other similar materials. Discriminated markings must be put on the cables to know path and place of the cables when performing future excavation to avoid them.

- If group of cables are laid beside each other in the trenches, must keep sufficient distance between them in order not to affect their efficiency for carrying the current (see distances table in code annexes).

- Trenches are backfilled as soon as possible after laying the cables to reduce possibility of damage.

- If the cables are passing under the roads that move on them heavy vehicles, it is preferred to pass the cables in ducts and to leave paths for an additional cables in the future without the need to excavate the road again.

- When laying the cables inside troughs, must take into consideration effect of adding more cables in the future that may adversely affect cable load (current density).

- Cables installed in the air must be fixed at near distances in order not to apply stress on the cable (see code annexes)- IEC instructions. When passing the cables on trays and stairs, must take into consideration places of these trays and stairs as the workers at the site consider them as walkways to access to the surrounding areas that may damage the cables.

- For all method of cables installation, must not bend the cables with radius less than that indicated in the tables for this regard and specified in the international standard IEC or Egyptian standards.

It is preferred to be the radius little greater that than specified in these specifications.

- When passing the cables across the walls and partitions, must be passed through holes lined with fire resistant material. This shall be applied when ascending or descending the cables across different floors ceiling of the building.

- It is preferred to use cables with lead sheath in a ground saturated with hydrocarbons to prevent its leakage through cables insulation or reach to the electrical boards and cause fire.

- When passing (drawing) cables inside ducts, must take into consideration, in addition to the generated heat, easy drawing of cables inside the ducts without causing any mechanical stresses.

- Distance between the draw boxes and the used number of elbows in the path affect on the required tension for cables laying, so this must be taken into consideration where the increase of stresses leads to damage of cables insulation. Code annexes show duct factors according to the standard specifications and cables factors for different sizes.

5-4 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).

5-5 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 cannot 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.

6- 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.

6-1 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 plates, steel sections, hoses, paving materials and metal products and their alloys.

6-2 Accessories

They include hinges, lockers, handles, latches, faucets and valves, knobs, taps, valves and mixers.

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.

6-3 Equipments

They include motors, pumps, generators, cables, distribution and control boards, valves, boosters, 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.

6-3-1 Tests at Works

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.

6-3-1-1 Hydraulic Pressure Test

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.

6-3-1-2 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.

6-3-1-2-1 Electrical Motors 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.

6-3-1-2-2 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.

6-3-1-2-3 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.
- Inspection of performance accuracy of electrical control panel.

C- Before shipment

- Final visual inspection and revision of markings and ensure fitness of equipments sealing.

- Revision of final dossier.

6 – 3 – 1 – 2 – 4 – Pumps:

- Revision of the routine tests certificates
- Performance test
  (Flow – head – rotation speed – motor ability analysis – efficiency – performance curves – vibration – materials – paints and ceiling treatment)
- Visual inspection and dimensions
- Inspection of data board
- Inspection of documents and insulation

6-3-2 Equipments tests at site

6-3-2-1 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.

6 – 3 – 2 - 2 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.

6 – 3 – 2 - 3 Electrical distribution boards

The following tests are performed after installation of the boards at site:

- Inspection of interconnections.
- High voltage test
- Ensure performance safety according to check list indicated in annexes.

6 – 3 – 2 - 4 Electrical Cables

After installation and laying the cables, the following tests are performed:

- **Isolation test with megger using the voltage of 500 V to ensure the following:**

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.

6-3-2-5 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.

6-3-2-5-1 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 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.

6-3-2-6 Electrical Switchgears

6-3-2-5-1 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.

6-3-2-6-2 Measurements

- Measurement of electrical insulators resistance.
- Measurement of cables resistance by megger.
- Measurement of bus bars by megger
- Measurement of earth network resistance.

6-3-2-6-3 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.

6-3-2-7 Equipment Tests

6-3-2-7-1 High Voltage Test for Switchgear

- 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.

6-3-2-7-2 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.

7- Performance Tests and Handing Over

Introduction

Performance and handover tests of pumping stations are divided into two main parts:

First: 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.

Second: 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.

7-1 Steps for allowed performance tests and standards:

First: Equipments performance tests

7-1-1 General Conditions

a. 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.

b. 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.
c. 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.
d. Submit O&M manuals for the units.

7-1-2 Tests before connecting electrical supply

A- Insulation tests by Megger

- Measuring cables insulation and contents of distribution board according to standard values.

B- 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.

C- Control circuits tests

- Inspection of all control circuits to verify their efficiency according to tender conditions and specifications of the project.

D- 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.

E- Earth resistance measurement

Earth resistance is measured by calibrated ohm meter. Earth resistance must not exceed 1 ohm/m except otherwise mentioned in tender specifications.

7-1-3 Tests after connecting electrical supply

A. 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.

B. 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

7-1-4 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.

7-2 Boosters preliminary handover tests

In purpose of making sure of the efficiency of the pumps units in the operation of head, all tests made for the performance of the pumps as a whole. This is also to make sure that they perform their rated role and that water reaches to the next stages for a period not less than 3 days. Moreover, the work of the controllers and levels has to be checked according to the design stated in the conditions, technical specifications and drawings book. Any other necessary trials shall be made.

List of Construction and Building Codes issued from the Center

No	Code Name	Code No
1	Design Criteria and implementation 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 Part (20): Technical Terminology Part (21): Dictionary of Soil Mechanics and Foundation Engineering (3 Languages) Part (22): Soil Mechanics Code Guide Book	202 / 10 202 / 20 202 / 21 202 / 22
6	Design and Execution of Reinforced Concrete Constructions Part (10): Design Aids Part (11): Construction Data and Drawings Preparation Guide Part (12):Concrete Materials Lab Tests Guide	203 203 / 10 203 / 11 203 / 12
7	Design Criteria and Implementation Rules of Building Works: Part (1): Site Works 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 / 2 204 / 3 204 / 5 204 / 6 204 / 7 204 / 8
8	Steel Construction and Bridges	205
9	The Egyptian Code of Design Criteria and Rules for using fiber-reinforced polymers in construction fields	206
10	Design Criteria and Rules for using fiber-reinforced polymers in construction fields	208
11	Design Criteria and Rules of Sanitary Installations Engineering in Buildings: Part (1): Sanitary Installations for 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.	301 301 / 1 301 / 2 301 / 3 301 / 4
12	Design Criteria and Rules of Electrical Connections and Installations in Buildings: Part (1): Basics Part (2): Basics	302 302 / 1 302 / 2

	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 / 3 302 / 4 302 / 5 302 / 6 302 / 7 302 / 8 302 / 9 302 /10
13	Design Criteria and Rules of Electrical and Hydraulic Elevators in Buildings (English)	303
14	Design Criteria and Rules of Electrical and Hydraulic Elevators in Buildings (Arabic)	303
15	Air Cooling and Conditioning Volume (1): Air Conditioning Volume (2): Cooling Volum2 (3): Control and Electricity Works	304 304 / 1 304 / 2 304 / 3
16	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
17	Egyptian Code for Improving Energy in Buildings, Part (1): Residential Buildings Part (2): Commercial Buildings	306 / 1 306 / 2
18	Design Criteria and Rules of External, Internal and Special Painting	401
19	Egyptian Code for Using Treated Sanitary Drainage in Agriculture Field	501
20	Design of External Areas and Building for the Disabled.	601

List of Annexes and Dictionaries Complementary for the Codes

No	Annex Name	Code No
1	Dictionary of Soil Mechanics and Foundation Engineering (3 Languages)	202 / 21
2	Soil Mechanics Code Guide Book	202 / 22
3	Design aids with examples according to Egyptian Code	203 / 10
4	Construction Data and Drawings Preparation Guide	203 / 11
5	Concrete Materials Lab Tests Guide	203 / 12

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 in buildings (Part 1 and Part 2)	902 / 12
18	Specifications of thermal insulation work "Design criteria and implementation rules".	902 / 13