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. 169/1997

Volume II
Treatment Works
(Wastewater)

Fourth Edition
2008

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Wastewater Works

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. 169/1997. Housing & Building Research Center shall publish, identify and train on this code for the development of sanitation works in the Republic.

With God's Blessings

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

Ministry of Housing, Utilities and Urban Development
Minister Office

Ministerial Decree No. 169/1997
Concerning the Egyptian Code of wastewater treatment 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 05/06/1997.

Decided the following:

Article (1): Part (2) of Egyptian Code Concerning Design Criteria and Rules of Sanitary Drainage Pumping Stations shall be applied.

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

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

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

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

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.

Volume 1: Pumping Stations

Volume 2: Wastewater treatment works

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:

- National Authority for Potable Water and Sanitary Drainage

- Cairo General Organization for Sanitary Drainage
- Consultation Office for Sanitary Engineering (SANIS)
- Faculty of Engineering, Cairo University
- Faculty of Engineering and Technology, Suez Canal University

Chairman of Standing Committee

Prof. Dr. Eng. Ibrahim Hilal El Hatab

Standing committee

For

Preparation of Egyptian Code Concerning Design Criteria and Rules of Potable Water and Sanitary Drainage Treatment Plants and Pumping Stations

Members of Standing Committee:

Professor Dr Eng. (Deceased) Mohamed Mustafa El Saeed

Professor Dr Eng. Ibrahim Hilal El Hattab (Chairman)

Professor Dr Eng. Abd El Kareem Mohamed Atta

Professor Dr Eng. Fatama Al Zahra'a Al Saeed El Rafaai

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Volume II
Treatment Works

(4- Potable Water and Sanitary Drainage Treatment Plants – volume 2)

Chapter 1
Studies

Introduction

At the beginning of design liquid wastes treatment plants coming from a city, village or community, the following studies should be performed:

1. Number of people and different activities.
2. Determination of the design period.
3. Calculation of design flows.
4. Liquid wastes content
5. Properties of industrial liquid wastes allowed to be drained to sanitary drainage works.
6. Selection of treatment method
7. Disposal method and benefiting from products of treatment works.
8. Selection of treatment works site
9. General layout
10. Survey works.
11. Soil studies
12. Control and protection systems.

1. Number of people and different activities.

1-1 Stages of population growth

As treatment works are designed to service for a period ranging between 30-50 years, the implementation of project in a one stage is not economic, therefore the project will be implemented in stages according to economic and social growth stages of city, village or community with population increase as follows:

1-1-1 Start-up and prosperity stage

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

1-1-2 Stability stage

In this stage population attraction factors are stable and requires fixed population expansion and the population growth will be calculate by the arithmetic method.

1-1-3 Saturation stage

It is the reach to the decreased increase of population growth due to stop of attraction factors or as a result of construction of other adjacent residential communities with stronger attraction factors. The designer should take into consideration the difference between prediction in the population growth for existing urban community and new urban community.

1-2 Future estimation of population

Population at the end of design periods is estimated by using the statistics performed by the governmental bodies concerned with population studies in order to know the current and future population taking into consideration the expected growth and the expansion of different industrial, service and commercial activities.

To reach to this purpose, there are different scientific methods, some of them are performed through application of mathematical equations and others are through applying the statistics on the graphical drawings. The following are some of the mathematical methods used in predication of the number of people:

1-2-1 Arithmetic Increase Method

The applied equation is:

$$P_n = P_1 + K_a (t_n - t_1) \quad (1)$$

This method is represented graphically by a straight line

1-2-2 Geometrical Increase Method

The applied equation in this method is:

$$\ln P_n = \ln P_1 + K_g (t_n - t_1) \quad (2)$$

It is represented graphically by an increasing curve of first order

1-2-3 Decreasing rate of increase

The applied equation in this method is:

$$P_n = S - (S - P_1) e^{-K_d (t_n - t_1)} \quad (3)$$

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

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

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

K_a: Annual population increase rate in the arithmetic method (fixed rate)

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

K_d: Decreased annual population increase rate in decreasing rate of increase method.

S : Maximum value of expected population (saturation limit)

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

$\ln$: Natural logarithm for the base (e).

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

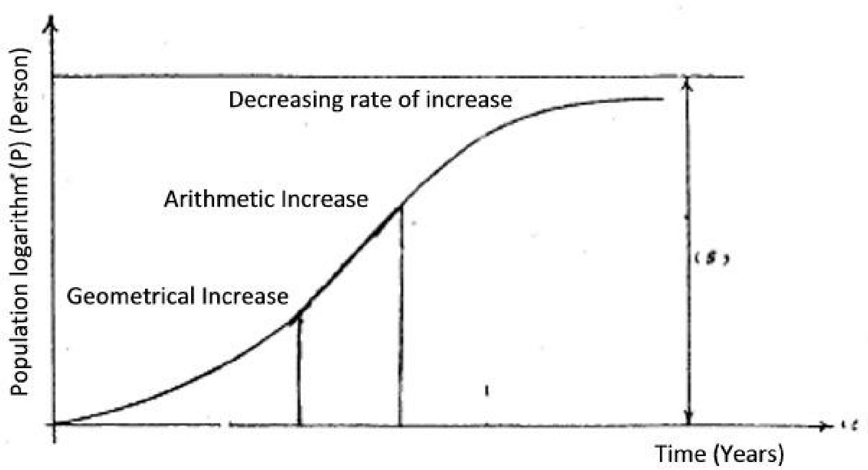


Fig (1-1) Population growth curve for the city

From the figure it is clear that the population growth of the city has an increase rate at the beginning then decreases by the growth of the city and decrease of the activities. The increase occurs with the geometric method in the growth periods due to the urban expansion or planning for new city with industrial, commercial or agricultural attraction regions, followed by a fixed increase expresses the stability of the city after the expected expansions. This increase is represented by the arithmetic method, and then followed by decreasing rates of increase due to decrease of economic resources of the city and being saturated and the lack of employment and migration from the city. This is represented by decreasing rate of increase method.

This is in addition to the following methods for estimation of population in the future.

1-2-4 Estimate of population by assuming population densities associated with land uses

This method depends on the method of planning of the city or region

Table (1-1) Shows population densities according to land uses

Table (1-1) Population densities used when calculating the expected population in planning of a city or region

Population Densities (person/hectare)	**Land Uses**
20-50	1st Class Villas
50-100	2nd Class Villas
100-250	Small Residential Buildings
250-700	Medium Residential Buildings
700-1200 or more	Big Residential Buildings
50-75	Commercial Areas
20-30	Industrial Areas

1-2-5 Graphical Extension Method

It is an approximate method resulted from it the future population by drawing population growth curve of the region in the past then it is extended to conclude the population at the required target year.

1-2-6 Graphical Comparison Method

In this method, population growth curve for the area under study is drawn for a city similar in activities with greater population then a curve similar to the curve of the population growth of the greater city is drawn, hence the required population growth in the future is deduced.

2- Design Periods

Design period of liquid wastes treatment works is divided into two stages, each stage ranges from 15-25 years, hence the total design period is 30-50 years

3- Calculation of design flows

When calculating liquid wastes design flows, their sources and quantities must be determined as follows:

3-1 Sources of liquid wastes

3-1-1 Residential uses

They are the liquid wastes collected from residential, commercial, service and recreational areas.

3-1-2 Industrial uses

They are the liquid wastes allowed to be drained to sanitary drainage works coming from different industrial processes.

3-1-3 Other sources

They are the water collected from rain water and infiltration water.

3-2 Liquid wastes flows

3-2-1 Average flow

The average flow is calculated as follows:

1. Annual base
2. Seasonal base

A- Summer average flow

B- Winter average flow

$$Q_{av}\ (\text{summer}) = (1.2 - 1.3)\ Q_{av}$$

$$Q_{av}\ (\text{winter}) = (0.7 - 0.8)\ Q_{av}$$

Any of the above average flows are calculated for sanitary drainage flows by multiplying average daily water consumption, either calculated annually or seasonally, by a reduction factor of (0.8-0.9).

$Q_{av.\ (waste\ water)} = (0.8 - 0.9)\ Q\ av_{\ (consumption)}$

3-2-2 Dry Weather Flow (D.W.F)

It is the flow resulted from the different consumption without adding rain water and is divided into:

3-2-2-1 Minimum Dry Weather Flow

This flow occurs during the night or during winter and is calculated from the following equation:

$$Q_{min\ D.W.F} = (0.2\ P^{1/6})\ Q_{av} \quad \text{..................................} \quad (1)$$

Where:

$Q_{min\ D.W.F}$	: Minimum dry weather flow (l/s)
P	: Population in thousand
Q_{av}	: Average flow (l/s)

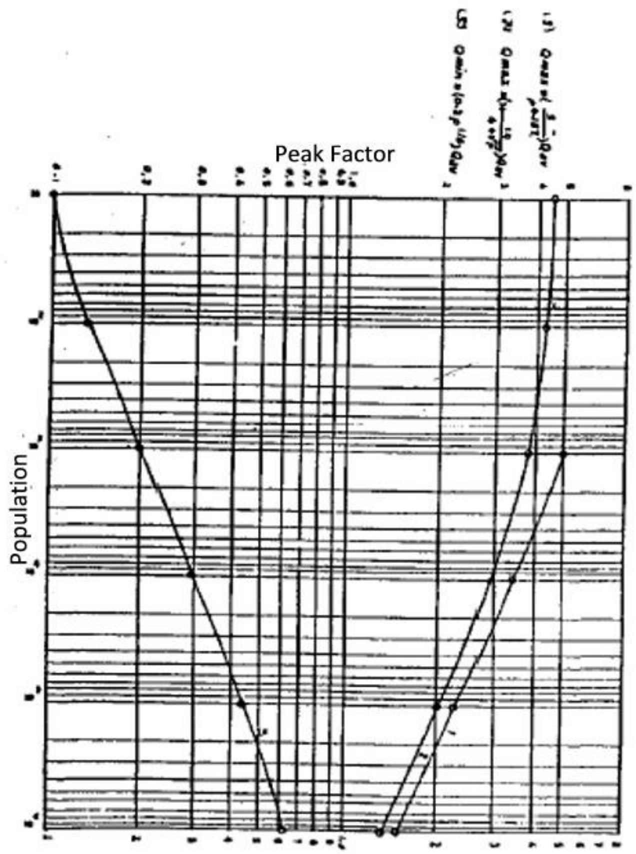
3-2-2-2 Maximum Dry Weather Flow

It is called peak hour flow that occurs in summer and is calculated form the following equations:

$$Q_{max\ D.W.F.} = \left(1 + \frac{14}{4 + \sqrt{p}}\right) Q_{av} \text{........................} \quad (2)$$

$$Q_{max\ D.W.F.} = \left(\frac{5}{p^{0.167}}\right) Q_{av} \text{..............................} \quad (3)$$

Fig (1-2) shows values of peak factors in case of minimum and maximum dry weather flows according to equations (1), (2) and (3).



Peak Factor

Fig (1-2)

3-2-3 Industrial Flow (Q_{indust})

In case of existence of areas for industrial activities for the city, the industrial flow is taken 1-2 l/s/hectare in case of unavailability certain data about the type of the industries.

But, in case of availability of this data, the flow will be taken according to the type of the industry.

3-2-4 Commercial Flow ($Q_{comm.}$)

In case of existence of commercial centers, the maximum flow is taken between (0.5-1.7) l/s/hectare.

3-2-5 Infiltration Flow ($Q_{inf.}$)

Infiltration water flows received at the network are calculated according to the head of infiltration water level over the upper trace of the pipe in the network taking into account to exclude the area at which infiltration water level is lower than the pipe line. In case of unavailable enough data, it will be taken as follows:

- 0.46 m^3/day/ 1 cm of pipe diameter / 1 km of the pipe line
- Or, 0.2 l/s/ hectare
- Or, 5-15% of the average flow.

3-2-6 Rain flow (Q_{rain})

Rain flow (Q_{rain}) is calculated from the following equation:

$$Q_{rain} = 2.75\, C*I*A \quad (\text{lit /s})$$

Where:

Q_{rain}: In the quantity of the rainwater that reaches to drainage line (L/S)

C: Excess Rainwater Factor

I: Intensity of rainwater fall (mm/hour)

A: The area exposed to rainwater fall served by the line (hectare)

Table (1-2) Excess Rainwater Factor

Type of Surfaces	(C) Values
1. Roofs and paved streets	0.70-.095
2. Clay soils, gardens and unpaved streets	0.10-0.40
3. Sand soil	0.2-0.05
4. Residential areas (flat)	0.30-0.50
5. Residential areas (Rocky)	0.50-0.70
6. Industrial areas (Light industries)	0.55-0.65
7. Industrial areas (Heavy industries)	0.60-0.80

3-3 Treatment plant design flows

When calculating the design flows, the following cases must be taken into consideration:

3-3-1 Existence of pumping stations

Maximum flow of current and future lift pumps must be taken as treatment plant design flow for current and future situation.

3-2-2 Non-existence of pumping stations

Current and future maximum flow of treatment plant main collector must be taken as treatment plant design flow for current and future situation.

3-4 Treatment plants design loads

Liquid wastes treatment plants design loads are divided into:

Hydraulic Loads

Values of the hydraulic loads are determined in case of average and maximum flows for liquid wastes. Unit of measure of hydraulic loads is m^3/m^2/day

Organic Loads

Values of the organic loads are determined in case of minimum and maximum flows for liquid wastes. Unit of measure of organic loads is $B.O.D_5$ /m^3/day.

3-4-1 Flows used in design of treatment units:

Treatment Units	Design Flow
• Design of pumping equipments and pipes. • Design of the following treatment units: - Intake and screens - Sand blocking tanks - Primary and final sedimentation tanks. - Pebble filters - Chlorine mixers	Maximum flow per hour (Average flow × peak factor)
• Design of pumping system and sludge return to aerators.	Maximum daily flow (Average flow × "1.8-1.5")
• Design quantity of the blocked materials on screens and the precipitated sand in sand blocking tanks.	Maximum daily flow (Average flow × "1.8-1.5")
• Design of measuring and control devices	Maximum flow per hour (Average flow × peak factor)
• Design of plant data recording devices.	Maximum daily flow (Average flow × "0.7-0.8")
• Design of chemicals and equipments stores.	Maximum daily flow for maximum month (Average flow × "1.2-1.3")

Treatment Units	Design Flow
• Design of pumping unit equipments in case of minimum flows (stop and operation) and design of small range flow meters. • Design of intake channels to control sedimentation of the suspended substances. • Sand filters and water treatment • Selection of minimum number of units operating during minimum flow periods.	Minimum daily flow (Average flow × "0.7-.08")

3-4-2 Organic loads used in design of treatment units

Treatment Units	Organic loads kg/day (Q m^3/day × B.O.D$_5$/m^3)
• Design of biological treatment units	Maximum daily flow (Average flow × "1.8-1.5" × B.O.D$_5$ kg/m^3)
• Design of sludge thickening and dewatering system.	Maximum daily flow for more than one day (Average flow × "1.5-1.6" × B.O.D$_5$ kg/m^3)
• Design of sludge mechanical treatment system	Maximum daily flow for maximum week (Average flow × "1.5-1.6" × B.O.D$_5$ kg/m^3)
• Design of sludge storage equipments and preparation of sludge as fertilizer.	Maximum daily flow for maximum month (Average flow × "1.2-1.4" × B.O.D$_5$

	kg/m^3)

4- Content of liquid wastes

When determining values of liquid wastes pollutants, the following cases must be taken into consideration:

1. Cities, communities or villages serviced by sanitary drainage networks, in this case similar samples will be taken over the year for the liquid wastes from the end of the network. The sample will be taken and the laboratory analyses will be performed according to Waste Environmental Federal (WEF) standards.

2. Cities, communities or villages planned or un-serviced by sanitary drainage project. In these two cases, city or village similar in social, economic, residential and industrial activities, and have the same climate conditions, shall be taken as guidance.

   In case of unavailability of similar city or village as guidance, quantity of B.O.D$_5$ will be estimated by average annual consumption of daily water per person and oxygen demand per person which ranges between 60-70 g/person/day in order to determine the organic loads.

5- Criteria of the liquid wastes allowed to be drained to sanitary drainage works

Criteria of liquid industrial wastes allowed to be drained to sanitary drainage networks or treatment plants will be determined in accordance with Law 93/62 and Ministerial Decree No. 9/1988 as follows:

Item	Limits
Temperature (°C)	- < 40 °C
pH	- Not less than 6 and not more than 10
Suspended solids	- No more than 500 mg/L and sediments must not exceed 5 cm^3/L in 10 minutes and not more than 10 cm^3/L in 30 minutes.
BOD_5	- Not more than 400 PPM
COD ($Cr2O7^2$)	- Not more than 700 PPM
COD (Permanganate)	- Not more than 350 PPM
SULPHIDES	- Not more than 10 PPM
Cyanides	- Not more than 0.1 PPM
Phosphate	- Not more than 5 PPM
Greases, oils and resin materials	- Not more than 100 PPM
Nitrates	- Not more than 30 PPM
Fluorides	- Not more than 1 PPM
Phenol	- Not more than 0.005 PPM
Ammonia	- Not more than 100 PPM
Free chlorine	- Not more than 10 PPM
CO_2	- Not more than 1 PPM
Formaldehyde	- Not more than 10 PPM (HCHO)
Heavy metals: (silver, mercury, copper, Nickel, zinc, chrome, cadmium and tin)	- Not more than 10 PPM, individually or collectively, if the drained wastes are more than 50 m^3/day, and not more than 5 PPM if the drained wastes to sewer network are more than 50 m^3/day. - Sum of silver and mercury must not more than 1 PPM.

6- Treatment Methods

6-1 Introduction

After determining treatment objectives and referring to the applicable laws, treatment will be performed by comparison of properties of raw liquid wastes. Treatment is performed to remove pollutants from the liquid wastes to be reused and available alternatives will be studied and evaluated to select the best of them through revision and classification of the different methods.

Pollutants are removed from liquid wastes by natural, chemical and biological methods through units operate in various groups when selecting treatment systems. It is also necessary to study design criteria of each group.

6-2 Natural Treatment

It depends on natural forces (gravitation) and includes purification, clarification, sedimentation, floatation and filtration works; therefore it precedes any other treatment units.

6-3 Chemical Treatment

It depends on addition of chemicals before sedimentation, absorption and disinfection processes. In case of sedimentation, it will be as a result of chemical reaction of chemical material that collects and sediments the suspended substances. Absorption depends on attraction forces between the suspended substances and the formed chemical materials. Disinfection depends on oxidation of bacteria by fragmenting the surrounding wall.

6-4 Biological Treatment

It depends mainly on stabilization of organic materials biologically by removing some of their elements. Oxidizable organic materials are removed biologically whether they are suspended or dissolved.

Mostly, these materials are converted into gases and tissues of living cells that can be removed by sedimentation. Biological treatment is used to remove nitrogen and phosphorous from liquid wastes.

Biological treatment is also called secondary treatment including final sedimentation. It is recommended to determine type of treatment according to properties and concentration of pollutants required to be removed, whether by reuse of the treated water or disposes them. Most common pollutants in the liquid wastes and their removal treatment stage are classified in the following table:

Pollutant	Treatment Stage
Suspended solids	- Screening and chopping - Sand removal - Sedimentation - Filtration - Floatation - Clarification and sedimentation using or without using chemicals. - Natural methods including direct irrigation.

Pollutant	Treatment Stage
Degradable organic materials	- Activated sludge - Biological contact tanks (pebble filters and revolving biological discs) - Oxidation ponds - Sand filters - Chemical and natural systems - Sedimentation
Volatile organic materials	- Aeration - Removal of gases - Absorption of activated carbon
Disease-carrying bacteria	Sterilization by chlorine and its compounds - Ozone - Ultraviolet ray - Natural system
Organic Nitrogen	- Using growth of bacteria by nitrates and reduction of ammonia. - Using filtration medium by oxidation into nitrates and reduction into ammonia. - Process of ammonia extraction - Ions exchange.

Pollutant	Treatment Stage
	- Addition of chlorine by equal dose at break point on chlorine curve. - Natural systems
Organic phosphorous	- Addition of metal salts - Clarification using lime then sedimentation - Removal of phosphorous by biological treatment - Biological and chemical treatment to remove phosphorous - Natural systems
Non degradable organic materials	- Absorption by carbon - Tertiary treatment by ozone. - Natural systems
Heavy metals	- Sedimentation using chemicals - Ions exchange - Natural systems

Preliminary Wastewater Treatment

In preliminary treatment, materials that hinders operation and maintenance works are removed by using screens, chopping of blocked materials, removal of sand and similar materials that cause corrosion or blocking of equipments as well as floatation for removal of oils and greases.

Primary Wastewater Treatment

In primary treatment, part of organic and inorganic suspended solids are removed by using units depend on natural treatment such as primary sedimentation in which about (50-70%) of suspended solids and (30-50%) of the organic materials (BOD_5) are removed according to stay period. Removal percentage can be determined from Fig (1-3).

Secondary Wastewater Treatment

In secondary treatment, degradable organic materials are removed biologically as well as the resulted suspended solids. Disinfection is a part of the secondary treatment. Conventional secondary treatment is defined as group of phases used usually in removal of organic material, where the biological treatment is performed by using activated sludge, contact biological tanks or oxidation ponds in addition to final sedimentation.

Nitrogen and phosphorous can also be removed by adding metal salts to mixture of suspended solids in the aerator, where this leads to removal of phosphorous in final sedimentation tank. Control of aeration system in activated sludge tank leads also to obtain nitrates then converted to ammonia for being disposed from the treated water (aerobic and anaerobic treatment).

Tertiary Treatment

In tertiary treatment, higher percentages of pollutants are removed, which can not be removed in the secondary treatment.

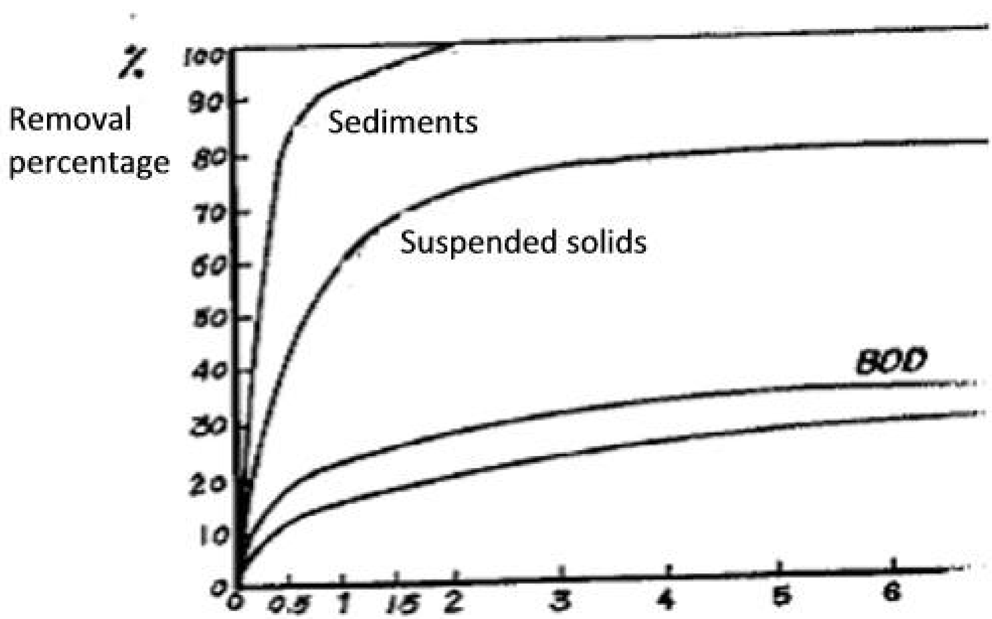


Fig (1-3): Removal percentage of sediments, suspended materials and organic materials in sedimentation tanks

7- Selection of treatment method

To select method of treatment appropriate with range of change of hydraulic and organic flows and loads that produces treated water with certain specifications, it is necessary to evaluate alternatives for integrated treatment units, the different methods as a whole and their effect to each other, e.g. balance of flows during the day represents one of the methods that reduces the loads on the treatment units. Also, the effect resulted from method of treatment of liquid wastes represents production of different amounts of sludge affect the alternative methods of sludge treatment, which represents an essential component of evaluation, also, balance of solid materials in the treatment method represents essential part in evaluation of treatment efficiency.

The following are the factors affecting selection of treatment method

The Factors	Remarks
1. Method appropriateness	This item is evaluated according to the previous experience, published results, achieved results in complete plants and from the laboratory experiments. In case of existence of new methods, trial studies must be performed.
2. Liquid wastes flows	The selected method must be appropriate for the flows coming to the plant
3. Accommodation of change of flows	Treatment units and methods must be designed to meet range of change in flows, where most of the methods are working efficiently when the flow is constant, but if there is great change in flows, it should be balanced.

The Factors	Remarks
4. Properties of liquid wastes	Properties of liquid wastes affect types of the selected treatment, e.g. it may be of chemical or biological type and then precautions must be taken to obtain the required characteristics of the treated water.
5. Affecting and non-affecting materials on treatment works	The materials that affecting or which have indirect effect on the treatment must be detected.
6. Air temperature	Temperature affects most of the chemical and biological reactions, and also affects the operation of equipments. High temperatures stimulate emission of odor.
7. Reactions and selection of treatment bed	Sizes of the bed depend on the main reactions inside the bed. Information about the reactions are resulted form the experiment, published researches and results of the studies performed on filed trial units.
8. Compliance with the regulating laws	Performance efficiency is measured usually by the properties of the treated liquid wastes, which must be in conformity with the regulating laws.
9. Products of purification process	Types and quantities of solid, liquid and gaseous materials resulted form treatment must be identified and their quantities must be known. Usually, field

	trial units are used to identify them and know their quantities.

The Factors	Remarks
10. Sludge treatment	Before selecting method of sludge treatment that appropriate for liquid wastes treatment units, it should first check if sludge treatment and disposal is useless or expensive and the possibility that wastes of sludge treatment may affect liquid wastes treatment units.
11. Environmental Commitment	Environmental factors, such as the prevailing wind and its direction and proximity to population centers, may affect the selection of specific methods. Traffic may also affect the selection of purification site. There may be also regulations for water bodies that receive effluent and requiring the removal of certain components such as organic materials.
12. Chemical requirements	Sources and quantities necessary for suitable period must be determined for the success of operation of treatment stages, and to determine also the effect of adding chemicals to the liquid wastes after treatment and their cost.
13. Power requirements	Power requirements and their future cost must be determined, especially if the treatment is designed to purely economic grounds.

14. The operators	Number and qualification of operators involved in the treatment process must be determined and to know also their skills and level of the suitable training.

The Factors	Remarks
15- Operation and maintenance needs	Operation and maintenance needs, required spare parts, their availability and cost must be determined.
16. Treatment assistance methods	Assistance methods and their effect on improving quality of treated liquid wastes in removing pollutants must be determined.
17. Efficiency of treatment works	Dependence on the proposed treatment units for a long period, evaluation of the method or performance of the treatment plant, overcoming the sudden loads and the effect of this on quality of the treated liquid wastes must be determined.
18. Operation	Method of operation, emergency cases, covering theses cases and level of training required for the operators must be determined.
19. Development ability	Ability of the existing treatment plant for development and expansion.
20. Availability of area	Availability of area necessary for current construction of the treatment plant and for future expansion.

8- Method of disposal and benefiting from treated works wastes

8-1 Treated liquid wastes

Treated liquid wastes water are disposed by discharging in the agriculture drains or in saline water bodies, such as lakes connected with seas or in the seas, provided that properties and standards of the treated water elements are in conformity with the provisions of Law No. 48/1982.

Treated liquid wastes water can be also used in irrigation of agriculture lands, provided that properties and standards of the treated water elements are in conformity with the provisions of Law No. 93/1962 and the Ministerial Decree No. 9/1988.

8-2 Sludge

Sludge resulted from treatment of liquid wastes represents great problem for its disposal because it is of big size and contains high percentage of water as well as micro-organisms that cause diseases. Therefore, sludge must be treated before disposal without causing any environment pollution.

Sludge resulted from treatment of liquid wastes is in the form of liquid or semi-liquid, where the concentration of dry solid materials ranges from 5-12%. Properties of the resulted sludge vary according to the used treatment system.

8-2-1 Sources and properties of sludge

8-2-1-1 Sludge resulted from primary sedimentation tanks

Concentration of dry solid materials ranges form (4-8) % with grey color and have a very unpleasant smell.

8-2-1-2 Sludge resulted from final sedimentation tanks

Properties of this sludge vary according to method of biological treatment that precedes final sedimentation tanks.

8-2-1-2-1 Biological filters

Concentration of dry solid materials ranges from (1-3) %. They are in the form of flocks of brown color and relatively pungent smell.

8-2-1-2-2 Activated sludge

Concentration of dry solid materials ranges from (0.50-1.50) %. They are in the form of flocks of blackish brown color and have no smell, but when converted to anaerobic state they will have a dark color.

8-2-2 Sludge Treatment

Purpose of sludge treatment is to separate percentage or most of its water and stabilization of the organic materials. There are two common methods used for sludge treatment before its disposal.

8-2-2-1 Thickening

Sludge thickening is the separation of percentage of water by collecting and concentrating of solid materials. This leads to decrease volume of the solid materials.

8-2-2-1-1 Gravity thickening

Sludge resulted from primary and final sedimentation tanks are supplied to upper center of circular beds. Thickened sludge exits from the bottom center of the bed to the dryer or the digesters and the supernatant water is supplied to heirs where it is collected and supplied to inlet of treatment process.

8-2-2-1-2 Floatation

Sludge particles are floated using compressed air. For success of this method and to get the best results, irrigated chemicals must be added, which collect and float sludge particles on the surface of the bed as a result of saturation with air. Floating sludge is scraped and transferred to drying beds (thickeners), sludge fermenters or any other system. The water separated from the sludge is pumped to the entrance of the treatment process.

8-2-2-2 Stabilization

In this method, organic materials in sludge are stabilized by oxidation or reduction, thus high percentage of micro-organisms that cause diseases can be eliminated.

There are many methods for stabilization of sludge components. The following two methods are commonly used.

8-2-2-2-1 Anaerobic Digestion

Anaerobic digestion is the stabilization of the organic materials that exist in the sludge in the absence of oxygen. This method depends on acid-forming bacteria and methane-forming bacteria, where methane bacteria feed on the organic acids forming methane gas and carbon dioxide. To control anaerobic digestion process, both sides of the reaction must be balanced and concentration of organic acids must be kept and prevented from accumulation.

Anaerobic digestion process is performed in closed beds supplied with sludge resulted from primary and final sedimentation tanks. Stabilized sludge is sucked to sludge drying beds or to any other system, while the floating water is pumped to inlet of treatment works.

8-2-2-2-2 Aerobic digestion

Aerobic digestion is the stabilization of the organic materials that exist in the sludge in the presence of oxygen. Aerobic digestion is similar to process of liquid wastes treatment using activated sludge, where the organic materials are oxidized using aerobic bacteria, which depend in its activity on oxygen. This reaction (oxidation) produces carbon dioxide and water vapor.

8-2-2-3 Sludge dewatering

Sludge treated by thickening or stabilization contains about 90% water and 10% solid materials, thus other methods must be used to separate greater amount of water with increase concentration of solid materials in sludge. There are many methods such as:

8-2-2-3-1 Drying Beds

In this method, raw sludge or pre-treated sludge is distributed to layers in open beds, one layer from sand under it pebble layer. At the bottom of the bed, there is a system for drainage of water leaked from the sludge. By this method sludge is dried by evaporation and leakage of water. This water is pumped to inlet of this process. After drying the sludge, especially raw sludge, it is stored in piles for decomposition of organic materials and removal part of bacteria. Code of Public Health issued from Ministry of Health indicates that the dried sludge resulted from treatment of liquid wastes can be used as fertilizer after drying period of not less than 45 days.

8-2-2-3-2 Centrifuge

Water is separated from the sludge pre-treated by thickening or stabilization with the addition of irrigated chemicals, which increase the amount of water removed from the sludge with the collection of sludge particles in the form of flocks through centrifugal devices (cylinders with perforated walls). By using this method, sludge with 30% concentration of solid materials can be obtained. Separated water that do not contain solid materials is pumped to inlet of treatment works, while it is not preferred to use the thickened sludge in fertilizing lands cultivated with food crops, where they contain proportion of chemical materials.

8-2-2-3-3 Filters

A- Vacuum Filters

The filter is a cylinder with perforated walls covered with the filtration medium (felts, fibers or industrial fibers).

The cylinder is rotating around a horizontal axis with its lower part immersed in sludge bed. By vacuuming air at the lower part of the cylinder, solid materials stick on the wall of filtration medium, while water penetrate the filtration medium which must be lifted to inlet of treatment works. Sludge removed from the filtration surface contains about 25% of dry solid materials. In this method, irrigated chemical materials must be added for sludge treatment before filtration process.

B- Sludge pressing filter

In this method, water is separated by filtration of water from sludge by pressing the sludge between two layers of porous fabric. After filtration, sludge contains 40% of solid materials. For increasing success of this method, sludge must be treated by adding irrigated chemical materials or polymers.

8-2-2-4 Sludge Disposal

1- In land

- It is prohibited to use raw sludge as surface fertilizer.
- Raw sludge is used as organic fertilizer distributed under soil surface.
- Sludge is used as surface fertilizer for cultivation of green spaces.

- Sludge is mixed with the soil, before or after treatment, and left for a period of one week for decomposing of organic materials, as it works to increase ability of the soil to absorb water.

2- In sludge Lagoons

Sludge lagoons are constructed for breaking, decomposing and drying sludge at the areas of porous soil away from source of groundwater, where the required area is double the area of sludge drying beds with depth 0.5-1.5 m.

9- Selection of treatment plant location

Treatment plant location must meet the following conditions:

- The site must be away from the residential area of the city or village, at a distance ranging 1-3 km.
- The plant must have access road with appropriate width and load.
- The site must be near as possible from place of final disposal of treated water (drain or cultivated land)
- The site must be under the prevailed winds.
- Soil study must be performed for selection of a site appropriate for economic construction.
- Plant future expansion must be taken into consideration.
- The site must be free from obstacles (gas pipes, covered drainage, power lines, high tension lines, etc.)
- Avoid agricultural lands as much as possible (it is preferred fallow land or desert) without prejudice to the economic study of the project.

10- Plant layout

Plant layout is prepared after determining method of treatment and selection of the site taking into consideration the following elements:

10-1 Survey elements:

- Site topography and dimensions.
- Link of the site with the public roads
- Direction of entrance of pipe lines of liquid wastes required to be treated.
- Survey and link the site with the places of disposal of the treated water.

10-2 Hydraulic Elements

- Proper planning of the treatment units to achieve the least possible losses so that the treated water can be drained to the final disposal places by gravity as far as possible.
- Exploitation of the natural inclinations, if any, to save construction works.
- Requirements of future expansion must be taken into consideration.
- Intersections between pipe lines must be decreased within the plant to facilitate implementation, maintenance and repair works.
- Reduce the lengths of sludge transmission lines, taking into account the absence of significant changes in their directions to reduce losses and to avoid the likelihood of blockage and sedimentation.

- Distribution of units and their linking together to allow ease of operation and achieve flexibility in emergency situations.
- Provide the site with the necessary facilities such as water supply networks for buildings, fire fighting, landscape irrigation, washing of treatment units and sanitation of buildings, site lighting and communications.

10-3 Architectural elements

- Site protection from external effects.
- Ease of movement between the treatment units, and between them and administrative buildings, service buildings and the presence of direct routes between them.
- Existence of field of view for all units across the operation and master control gallery.
- Taking into account that the administrative buildings and service buildings are suitable for the plant and away from noise sources, taking into account the directions of the prevailing winds to avoid exposure of the administrative buildings to unpleasant odor that is blowing from the inlets of the treatment process, treatment ponds or sludge drying beds.
- Construction of a high external fence around the site including entrances, security and information rooms.
- Architect coordination between plant buildings and units in terms of heights and dimensions necessary for ventilation and natural lighting.
- Adequate internal roads network.

- Provide the site with green areas and landscaping.

10-4 Structural elements

- Distribution of treatment units and service buildings must be taken into account, commensurate with studies of the soil to achieve economies of construction.
- Leave appropriate distances between the treatment units, and between them and other facilities and buildings to ensure ease of construction and reduce cost.

10-5 Mechanical elements

- Existence of adequate spaces between the units of the plant must be taken into account so as to facilitate installation, operation and maintenance works.
- The existence of appropriate areas for tanks and equipments installed outside the buildings.
- Appropriate area for store and workshop building.

10-6 Electrical elements

- Electrical power supply buildings must be near from main loads of the plant.
- Reduce the lengths and routes of electrical cables and do not conflict with the paths of pipes and channels as possible.
- Provide an alternative source of electric power in case of main power interruption.
- Taking into account central location of operating and control room with respect to treatment units from pumping station, air compressing stations, etc.

- Roads on which cables are passing must be with appropriate width to accommodate cable ducts and trenches with the required dimensions in accordance with the design.

11- Survey Works

Survey works are from the main elements on which design and distribution of project units, distribution and determination of appropriate places for these units are based, with optimum utilization of the economics in the used power, whether in terms of liquid wastes required to be treated, disposal of their products or interim movement between different treatment units.

Survey works are summarized in the following:

- Determination of north direction for the site.
- Network level works for the location distant according to nature of the ground and does not exceed 50 m in the two directions referred to the nearest bench mark or fixed point, whether it is a lock or bridge located on a water course or any other known level fixed point.
- Survey main landscapes around the site, such as roads, drains, canals, etc.
- 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.

12- Soil Studies

Soil studies report consists of the following components:

- Study of general layout of treatment works to determine places and depth of the borings.
- Study of the hydraulic sector of treatment units to determine depth of the required borings according to depth and loads of the constructions.

- Determine method of dewatering during construction.
- Determine quantity and quality of the cement used in construction in line with type of groundwater and soil.

Egyptian code on foundations and soil tests must be taken into consideration.

13 Control and Protection Means

Control and protection means is the system developed to control performance and efficiency of the treatment plant regarding operation safety, degree of treatment and fulfillment of standards required for the treated water.

13-1 Control means

Control of treatment units' efficiency and plant performance is performed as follows:

- Control of treatment units' operation levels to ensure flow of supernatant liquid wastes required to be treated and overcome hydraulic losses through heirs adjusted in a predefined limit.
- Control of supernatant flow velocity inside treatment units and connection channels to ensure function performance, whether for sedimentation or prevention of sedimentation by adjusting the cross sections.
- Control of flow diversion, isolation of any treatment units or the entire treatment line in order to perform maintenance or repair works by using valves and gates to be opened or closes as required.

- Control quantities of water, returned sludge, excess sludge or treated water using different types of flow meters.
- Control of treatment efficiency by adjusting and measuring of standards of each stage of treatment using many measuring devices, such as measuring of dissolved oxygen, pH, turbidity, temperature, conductivity and weather measurements.
- Control of chlorine quantities injected for supernatant sterilization coming out from the plant through water flow control or by using the residual chlorine.

13-2 Protection means

Treatment plants are protected as follows:

- Protection of the plant against flood or in emergency cases, such as failure or breakage of any of treatment units, channels or the pipes connecting between them through provision of bypass lines and dewatering equipments.
- Protection of plant equipments against stop of work in case of main power interruption by providing emergency generation units.
- Protection of electrical devices and equipments against voltage increase, decrease or overload.
- Protection against leakage of chlorine form sterilization devices.
- Protection against level increase in pump sumps over the maximum limit, or level decrease less than the minimum level.

Chapter 2
Design

1- Hydraulic Design

First: Primary (Mechanical) Treatment

1- Intake chamber

1-1 Purpose of the unit

Decrease water velocity and pressure in order to change flow system from closed course to open course for the water surface to be subjected to atmospheric pressure.

1-2 Unit Components

A chamber with dimensions fulfills hydraulic design criteria with many forms provided with a pipe for exit of sediments and discharge and overflow pipe.

1-3 Design Criteria

Stay period	: Form 0.5 to 1 minute
Horizontal velocity	: Form 0.6 to 1.2 m/s
Water depth	: Not less than intake pipe diameter + water depth in the connection channel and not more than 2 m in the direction of

horizontal flow.

2- Screens

2-1 Purpose of the unit

Blockage of the suspended or floated materials on water surface

2-2 Unit Components

They are channels provided with manual or mechanical screens. Manual screens are used in treatment plants with flow not more than 5000 m^3/day, while mechanical screens are used in the plants with flow more than 5000 m^3/day in the existence of manual screens used in the emergency cases.

Bars with circular or rectangular cross section are installed on the screens at inclination angle to the horizontal axis and extended to water surface. They are provided with gates in the front and rear of the bars to control water flow and overflow channel in case of manual screens. At rear of screens installed system for collection and transfer of the blocked materials.

Figures (2-1) and (2-2) show manual and mechanical screens.

2-3 Design Criteria

- Horizontal velocity through screen holes : 0.3 to 1.0 m/s
- Horizontal velocity component normal to the screens : Not more than 0.6 m/s

- Distance between bars: -

Fine screens : 25mm – 50mm

Coarse screens : 25mm – 75mm

- Screen inclination angle:

Manual screens : 45° - 60°

Mechanical screens : 60° - 80°

- Screens output: : 20 liter / 1000 m^3/ day
- Dimensions of bar cross section

Width : 1-2 cm

Length : 2-6 cm

Diameter (circular bars) : 1.5-3 cm

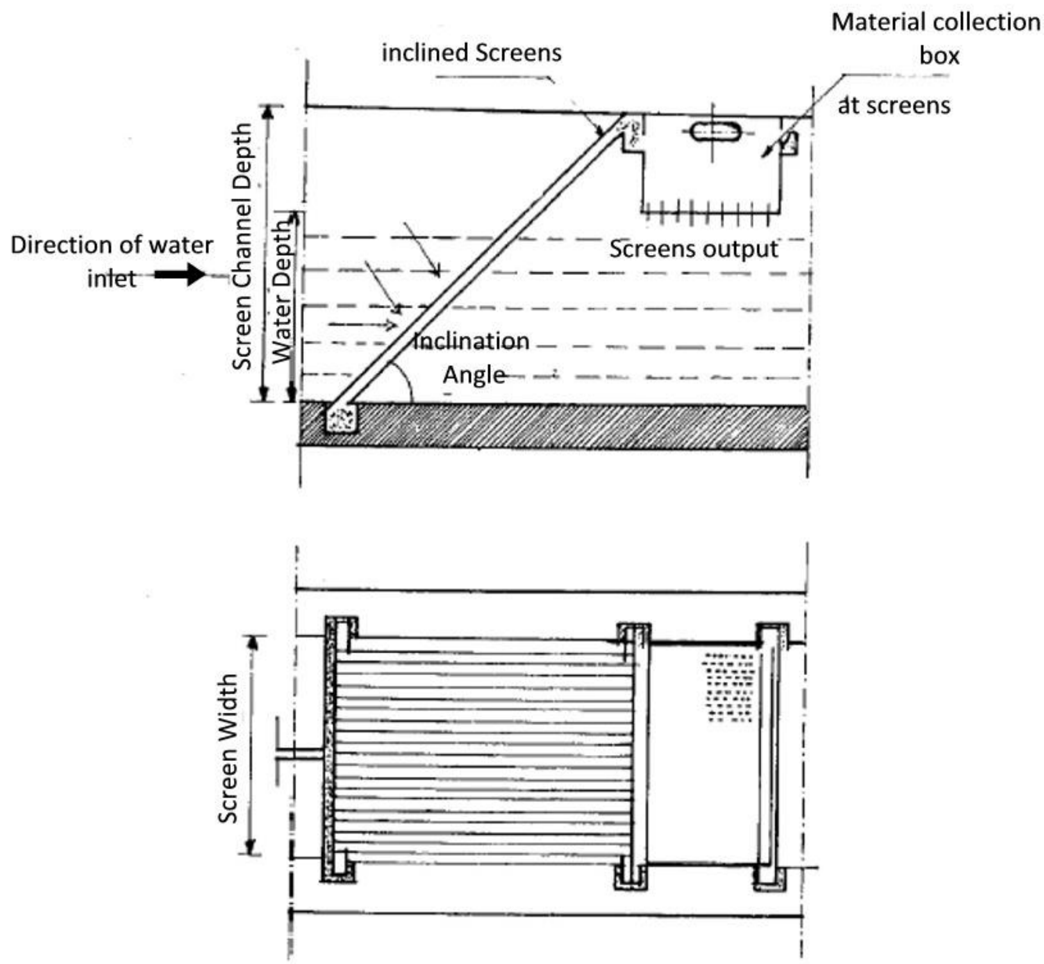


Fig (2-1): Manual Screens

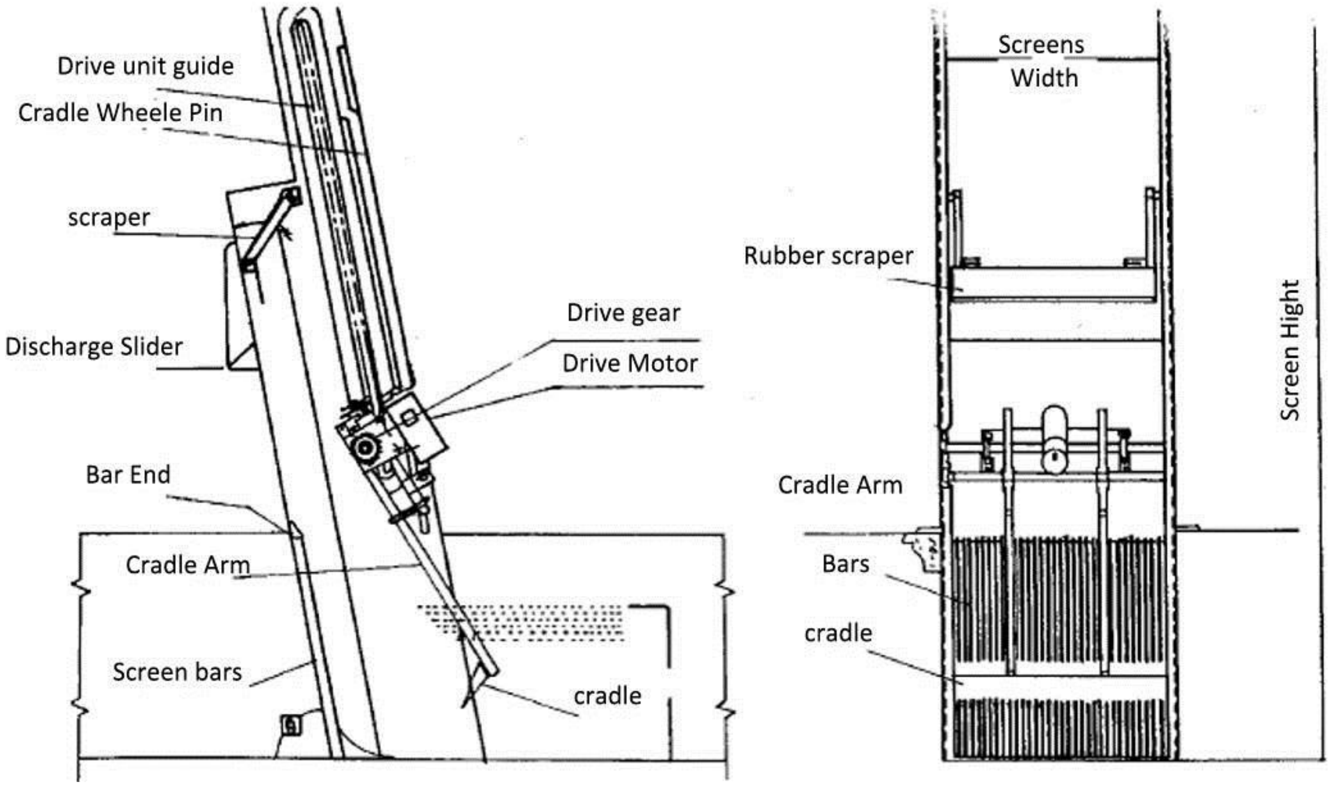


Fig (2-2): Mechanical Screens

- Head loss through screen : 10-15 cm

  (At start of operation)

- Equation used in calculation of head loss through screen:

$$h = B \left(\frac{w}{b}\right)^{4/3} h_v \ \sin \Theta$$

h = head loss (ft)

B = bar shape factor

= 2.42 (for sharp - edged rectangular.)

=1.83 for (rectangular semicircular upstream)

=1.67 rectangular semicircular upstream face & down stream face .

=1.79 for circular bars.

w = max. cross sectional width of bars facing direction of flow (ft)

b = min. clear spacing width of bars (m)

h_v = velocity head of flow approaching rack (m) $\frac{v^2}{2_g}$

Θ = angle between the screen and the horizontal plane.

3- Sand Separation beds

3-1 Purpose of the unit

It is used for sedimentation of sands and suspended inorganic materials with diameter not less than 0.2 mm and specific density not less than 2.65. It consists of channels provided with space for sand collection. It is divided into two types:

3-1-1 Horizontal flow sand separation beds

In this type, the flow is in the horizontal direction, where horizontal water velocity is controlled either by using parabolic shape channel or using proportionality heir installed on beds outlet.

Fig (2-3) shows circular sand separation bed.

3-1-2 Aerated sand separation beds

They are of rectangular shape, where the air is pushed from the bottom using diffusers installed on only one side of the bed in order to separate oils and greases whether stuck with the sand or not. The velocity is controlled in a way that the resultant water flow velocity is ranging from 0.25-0.3 m/s. Sand sediments are scraped and collected at the bottom of the bed either by using mechanical scrapers or using inclination at the bottom of the bed opposite to direction of water flow. The collected sands in the sand collection space are sucked either by using submersible pumps, screw pumps or gate valve installed at the bottom of sediments collection space. Sands are transferred and disposed by burial in the place allocated at plant site.

Fig (2-4) shows rectangular aerated sand separation beds.

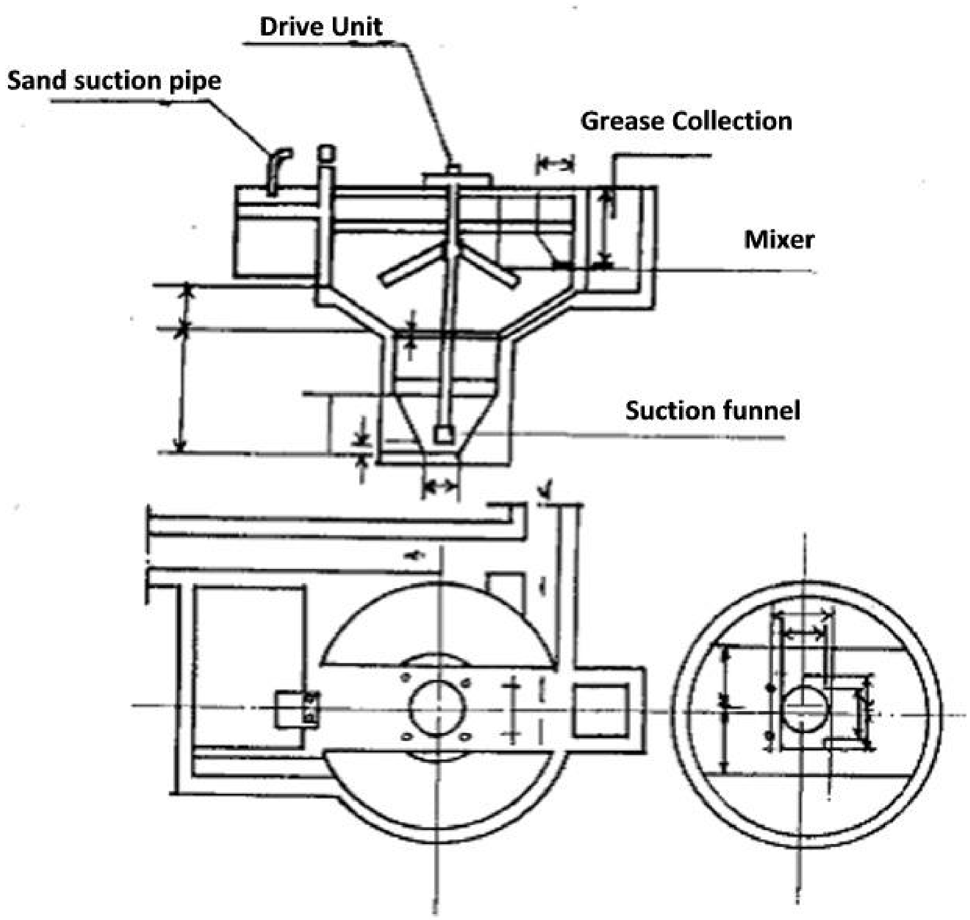


Fig (2-3): Circular sand separation bed

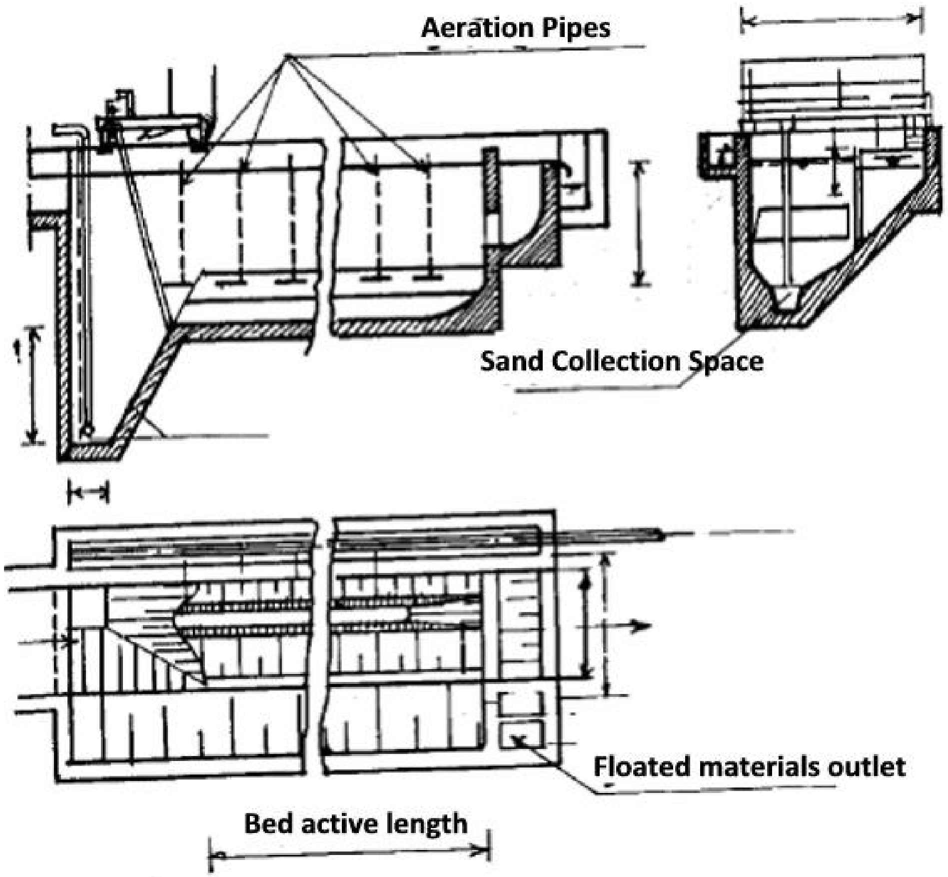


Fig (2-4): Rectangular aerated sand separation bed

3-2 Unit Components

Rectangular beds with dimensions fulfill hydraulic design criteria, where solid particles and sand granules sedimentation velocity is taken into consideration. The bed is divided into two parts at least. A gate is installed on each part, and proportionality heir or oil and grease heir is installed at bed outlet.

When designing sand separation beds, the following must be taken into consideration:

- Sand sediment sector must be with suitable dimensions to ensure formation of beds sector in a way that makes the horizontal velocity constant under different hydraulic conditions. Also, outlet heir level must be adjusted in a way that the water height is not less than 15 cm over the heir to allow sand sedimentation.
- Water is distributed after the sand sediments (through distribution chambers to primary sedimentation tanks) according to hydraulic paths whether for the current or future stage.

3-3 Design criteria

3-3-1 First Type: Horizontal flow sand separation beds

- Horizontal velocity : 0.25-0.5 m/s
- Stay period : 45-90 second
- Surface load rate : 1200 m^3 / m^2 / day
- Water depth : 60-100 cm
- Bed width : (1-2) water depth

- Vertical velocity : 2 cm/s for granules diameter greater than 0.2 mm
- Bed length : (20-30) water depth
- Quantity of sand sediments : (100-250) liter / 1000 m^3 of daily flow

3-3-2 Second Type: Aerated sand separation beds

- Stay period : 2-5 minutes
- Surface load rate : Not more than 1000 m^3 / m^2 / day
- Water depth : (0.3-0.5) m
- Helical water velocity : (0.1-0.2) m/s
- Horizontal velocity : (0.25-0.30) m/s
- Length : (7.50-20) m
- Bed width : Not more than 2 m
- Air supply rate : (0.3-0.7) m^3/min/ meter of bed length of average 10 m^3 / hour / m^3 of the bed.
- In case of existence of great amount of oils and greases in the liquid wastes in the form of fine suspended materials, floatation unit should be added after sand separation beds for improving biological treatment efficiency.
- Sand granules diameter must be greater than 0.2 mm
- (100-250) liter / 1000 m^3 of the sand sediments are obtained from the daily flow.

4- Primary sedimentation tanks

4-1 Purpose of the unit

It is used for sedimentation (30-40) % of suspended organic materials and greater amount of suspended inorganic materials of about (50-70) %, in addition to disposal of floatable materials. These tanks are supplied through distribution chamber after sand sediments. Sedimentation tanks are divided into two main types according to flow direction:

A. Horizontal flow sedimentation tanks as shown in Fig (2-5).

B. Vertical flow sedimentation tanks as shown in Fig (2-6).

Sedimentation percentage is selected according to the curve in Fig (2-7).

2-4 Unit Components

A- Intake area

Horizontal flow sedimentation tanks (Rectangular tanks):

- Inlet channel or pipe provided with gate or valve.
- Baffle wall assisting in sedimentation of the suspended materials
- Inlet channel installed on it heir.
- Water inlet velocity to sedimentation space must not exceed (0.25-0.3) m/s

The following must be taken into consideration:

Water inlet at the entire water cross section must be in the form of windows with equal spacing or heirs to ensure inlet water distribution in the tank.

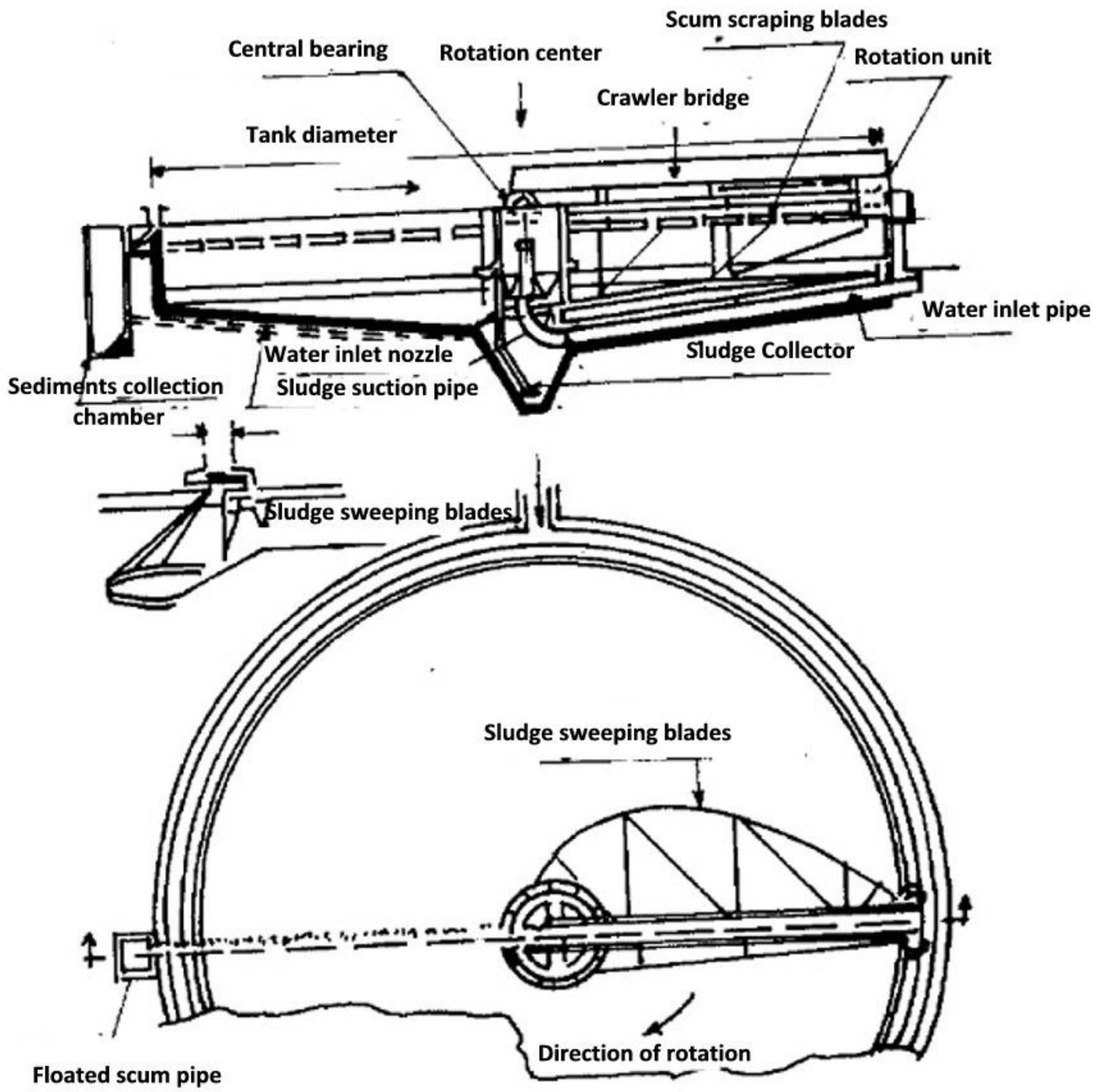
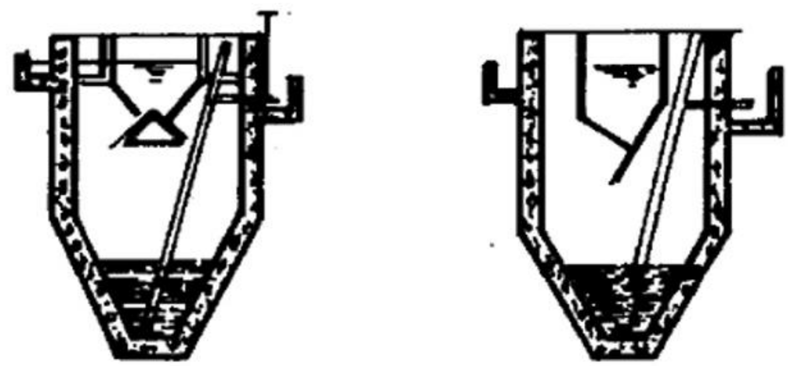


Fig (2-5): Horizontal flow circular sedimentation tanks



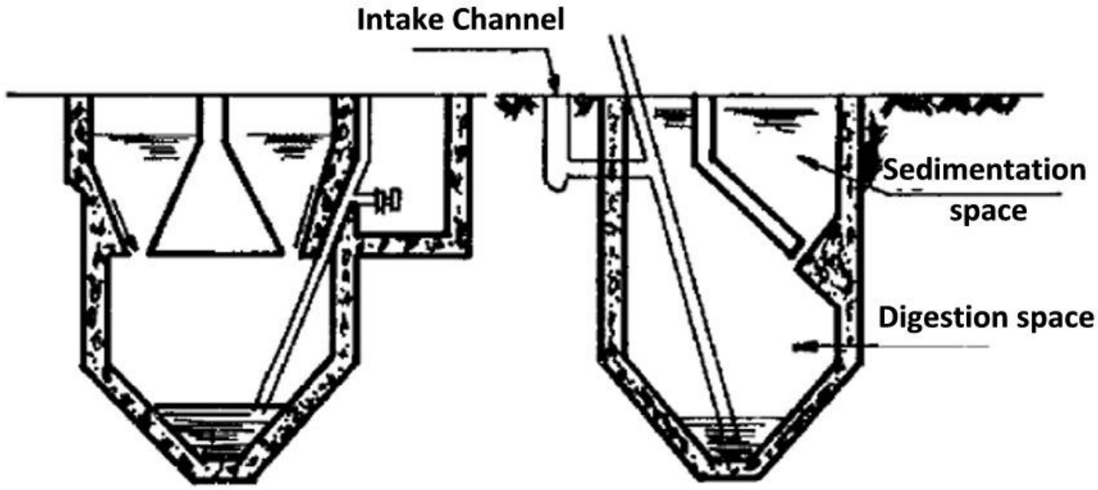


Fig (2-6): Horizontal flow sedimentation tanks (IMHOFF Tanks)

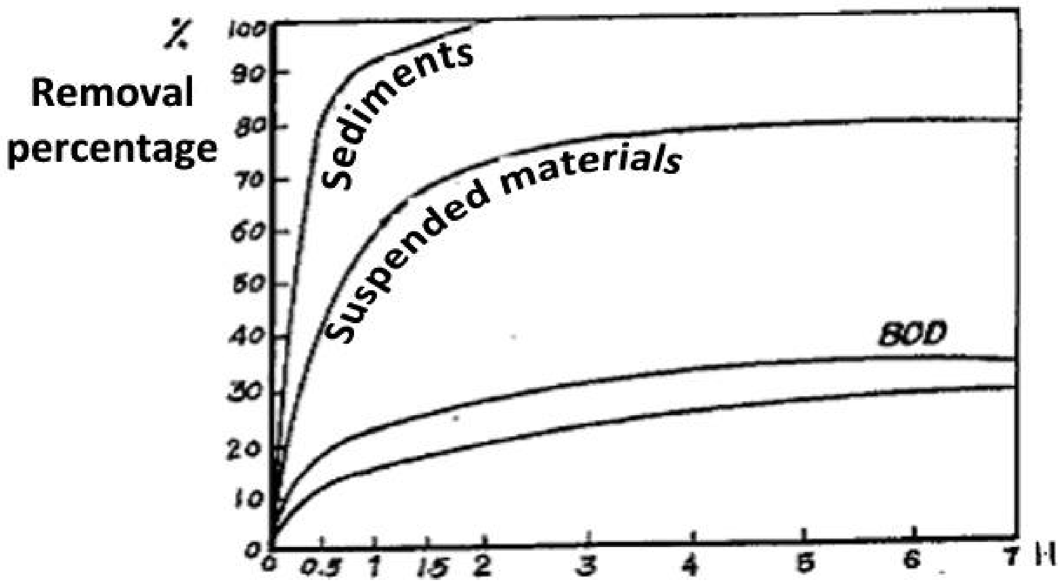


Fig (2-7): Removal percentage of sediments, suspended materials and organic materials in sedimentation tanks

Radial flow tanks (circular tanks)

- Inlet pipe provided with gate valve
- Vertical pipe outlet from tank center installed on it perforated cylindrical baffle for water distribution. Inlet pipe end level must be under water surface by about 50 cm. Velocity through holes ranges 0.25-0.3 m/s

B- Sedimentation area

Rectangular tanks

It is the area between inlet baffle and outlet baffle.

Circular tanks

It is the area between inlet baffle and outlet baffle.

C- Outlet area

Rectangular and circular tanks

1 Heir is installed on outlet channel.

2 Water outlet through channel or pipe.

3 Baffle is installed before outlet heir, which assists in preventing exit of floated materials.

D- Sediments collection area

Rectangular tanks

It is the area starts at the beginning of bottom inclination and extends to sedimentation collection space. The space is in the shape of inverted pyramid provided with a pipe for sediments exit installed on it gate valve and telescopic valve.

Circular tanks

It is the area starts from the beginning of tank bottom inclination and extends to the middle of the tank. It is in the shape of inverted incomplete cone provided with a pipe for sediments exit installed on it gate valve and telescopic valve.

Rectangular and circular sedimentation tanks are provided with crawlers for sweeping sediments from tank bottom, and are provided on the top by scraper for collection of floated scum from the water surface.

4-3 Design criteria

A- Rectangular tanks

Water side depth	: 3-5 m
Length	: Not more than 40 m
Width	: 6-12 m
Length: Width	: (1:3) – (1:5)
Floor inclination (for tank bottom)	: (1:40) or (1:50)
Stay period:	
Primary sedimentation followed by pebble filters	: 1.5-3 hours
Primary sedimentation followed by sludge activated beds	: 1-1.5 hours
Primary sedimentation without secondary treatment	: 3-4 hours

Surface load rate:

Primary sedimentation tanks without secondary : 1-1.33 m/hour treatment

Primary sedimentation tanks followed by biological filters	: 1-2.0 m/hour
Primary sedimentation tanks followed by aeration tanks	: 1-1.5 m/hour

Where:

$$\text{Surface load rate} = \frac{\text{Water depth}}{\text{Stay period}} \text{ m/hour}$$

B- Circular tanks:

Depth	: 2.5-4 m
Diameter	: Not more than 40 m
Bottom inclination	: (1:10) – (1:15)
Surface load rate	: As in rectangular tanks
Stay period	: As in rectangular tanks
Load rate at outlet rate	: 150-600 m^3 / m / day

Second: Secondary (Biological) treatment

1- Introduction

The purpose of biological treatment works is to covert dissolved and suspended organic materials, which are not sediment in primary sedimentation tanks, into suspended fixed materials that can be sediment by activating aerobic bacteria using micro-organisms through providing the necessary oxygen by exposing them to air, entering compressed air or continuous mixing inside liquid wastes. Bacteria are also activated by returning part of the sediment sludge in the final sedimentation tanks of a certain percentage, where it supplies the activated bacteria by the elements necessary for their growth. Biological treatment is divided into three main sections:

1-1 Contact and stabilization treatment

In this system, a layer or thin membrane of jellylike materials, which contain quantity of micro-organisms and bacteria, is formed on the surface of the contact medium, where the jellylike layer oxidizes and stabilizes the organic materials in the liquid wastes.

It includes the following methods:

1. Slow and high rate pebble filters.
2. Plastic filters and biological towers.
3. Biological discs.

1-2 Activated Sludge

- Conventional method
- Tapered aeration method
- Step aeration method.
- Completely mixed method
- Contact stabilization method
- Extended aeration method
- Oxidation ditch method
- High rate activated sludge.

1-3 Oxidation Ponds

- Natural oxidation ponds (Anaerobic, Facultative and Maturation Ponds).
- Aerated oxidation ponds (Aerated and Facultative Ponds)

2- Biological Filters

2-1 Purpose of the unit:

Biological filters are used to oxidize the organic materials and convert them to fixed materials than can be sediment and separated in final sedimentation tanks.

Principal of operation of biological filters is to form a layer or thin membrane of jellylike materials contain millions of micro-organisms and bacteria on the surface of the filtration medium for a period that may reach to two weeks. By forming this layer, the filter becomes usable. During treatment process, the organic materials are absorbed through this thin membrane by the micro-organisms, where they are decomposed partially and cause increase in volume, weight and thickness of the layer and lead to separate these layers.

2-2 Unit Components

Biological filters are constructed in circular tanks will walls from reinforced concrete or hard rocks, the bottom from reinforced concrete with an inclination at the bottom commensurate with the drainage system. The filter contains a filtration medium, which is usually from broken stones, pebbles or plastic materials. The water supplied from primary sedimentation tanks are sprinkled through rotated distributors with regular rate of water fall over filter surface area, where the arms are rotated by the difference in levels between the water in the primary sedimentation tanks and the revolving arms. After passing the filtration medium, water is collected through drainage system out of the tanks using collection channels.

Figures (2-8) and (2-9) show details of the biological filter. Fig (2-10) shows details of one of the models applied in underground drainage channels.

2-3 Design criteria

2-3-1 Slow rate filters

- Hydraulic surface load rate = 1-4 m^3/ m^2/ day
- Organic load rate = 80-320 (gm BOD_5 / m^2 / day)
- Filtration medium depth = 1.8-3 m
- It does not contain biologically treated water return lines.

2-3-2 High rate filters

- Hydraulic surface load rate = 10-30 m^3/ m^2/ day (include the returned water)
- Organic load rate = 500-1000 (gm BOD_5 / m^2 / day)
- In one or two stages.
- Filtration medium depth = 1.0-2.0 m

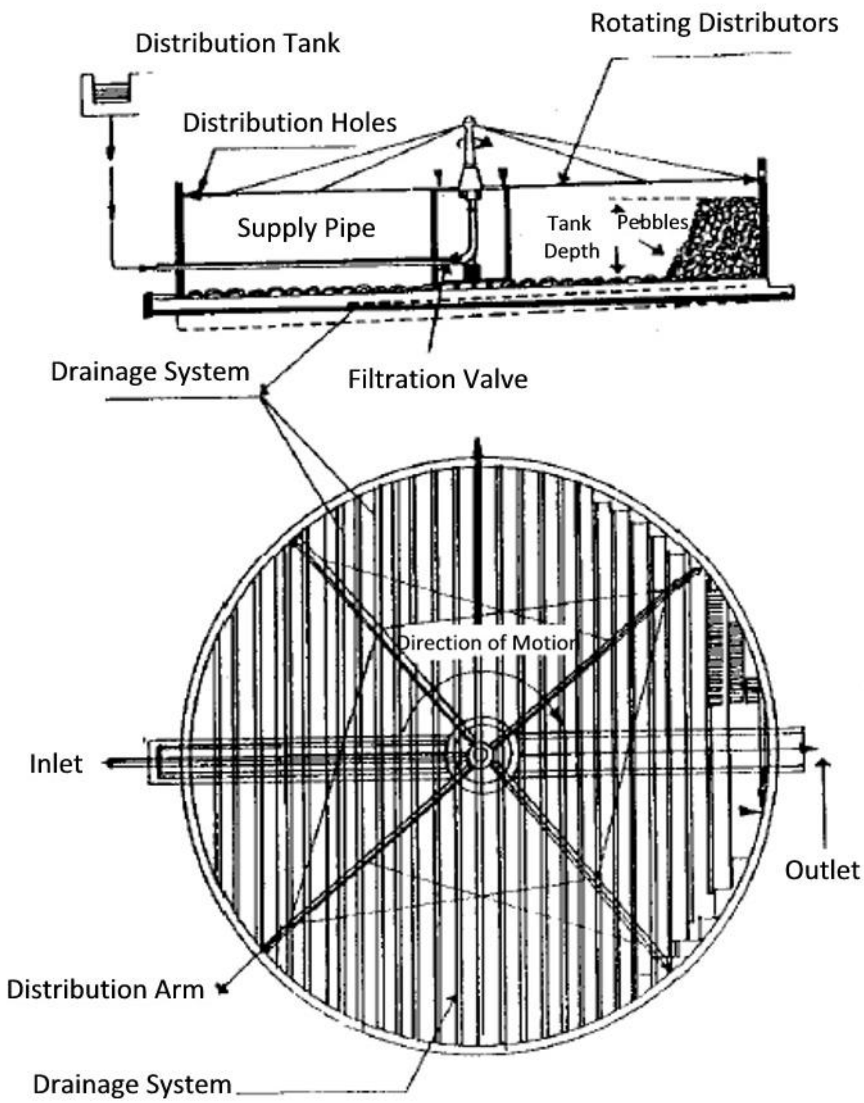


Fig (2-8): Biological Filter

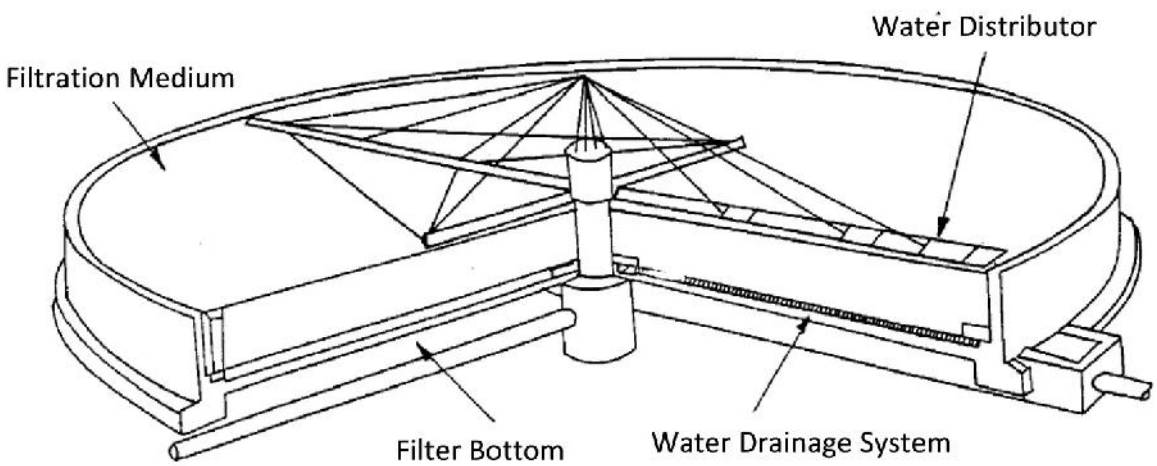


Fig (2-9): Biological Filter View

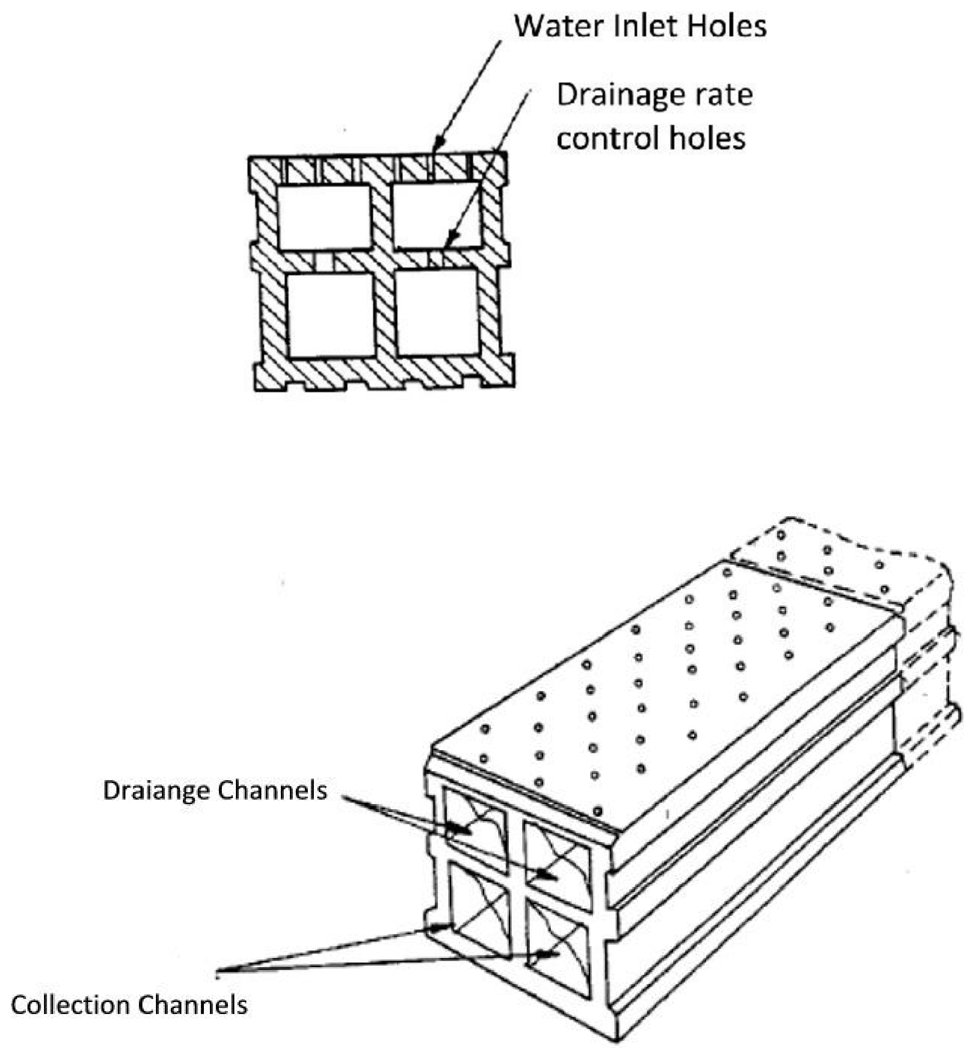


Fig (2-10): Drainage Channels

Ideal depth of the filter = (1.5-2.0) m in first stage = (1-2) m in second stage

- Return percentage ranges (0.5-3) provided that organic materials concentration does not exceed 150 mg / liter.
- Water return equation:

$$M = \frac{Ci - CM}{CM - Ce}$$

M = Recirculation ratio

Ce = effluent - concentration mg/l

CM = 150 mg/L

Ci = influent - concentration mg/l

- Pebble granules size = (5-10) cm

3- Revolving biological discs

3-1 Purpose of the unit

- Oxidation of organic materials and convert them to fixed materials that can be separated in final sedimentation tanks. Fig (2-11).

3-2 Unit Components

- It consists from light weight circular discs revolved in slow velocity and submersed to about their middle in a cylindrical base tank filled with sanitary drainage water. These discs are made usually from some types of plastic.
- During operation, the discs are submersed below the revolving shaft installed in the discs center so that 40% of their surface area is submersed in sanitary drainage water.

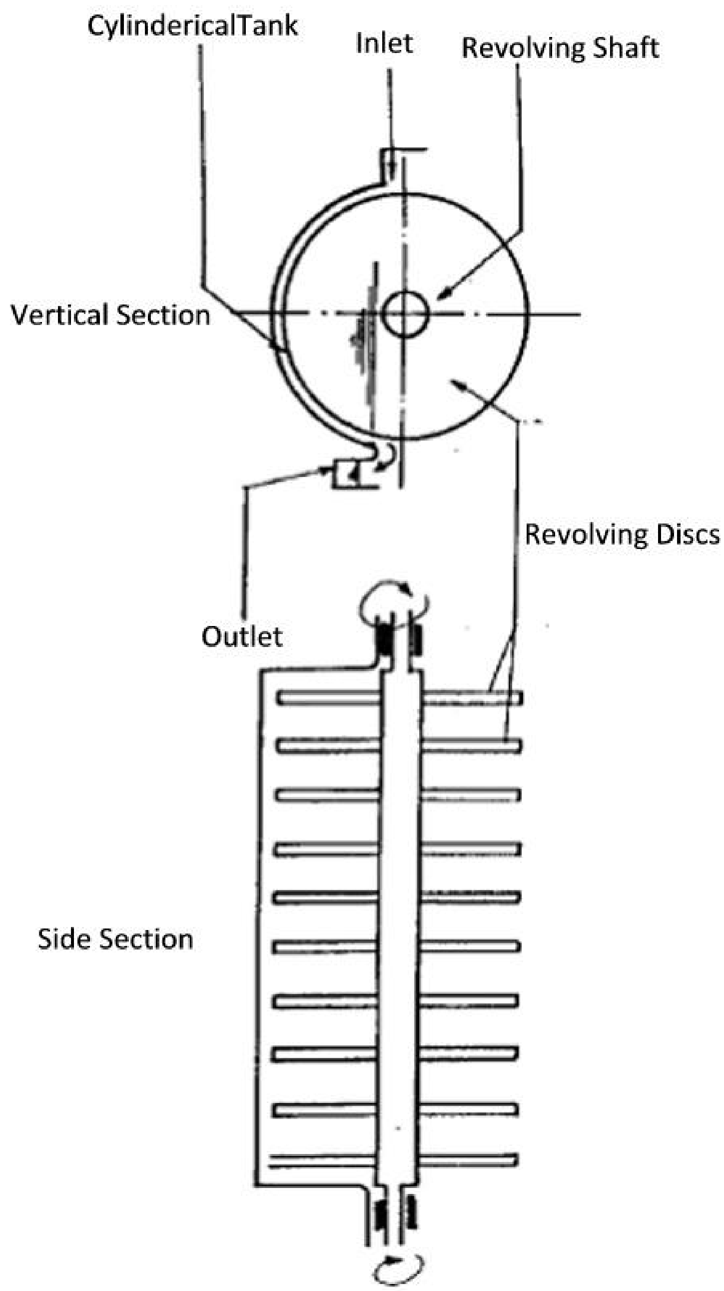


Fig (2-11): Revolving Biological Discs

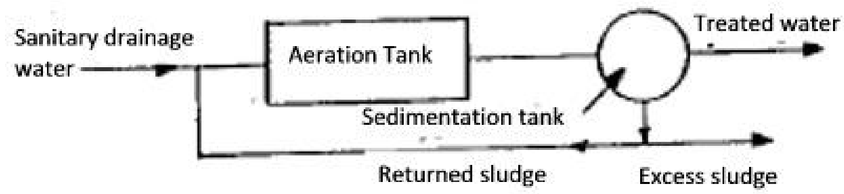
Due to this rotation, biological layer is formed on all surfaces of the revolving discs which performs the treatment process with immersion of the discs in the sanitary drainage water then exposed to the air wetted with drops of water.

3-3 Design Criteria

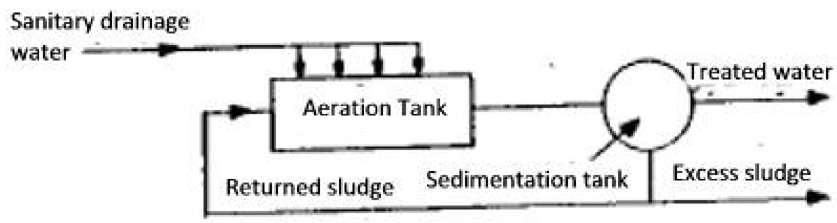
- Revolving disc thickness = (1-2) cm
- Disc diameter = (2-3.5) m
- Disc revolving speed = (1-2) rpm (in normal operation). Treatment efficiency can be increased by doubling this speed.
- Distance between centers of two discs = (30-40) cm
- Hydraulic load = (40-60) liter / m^2 / day
- Organic load = (55-210) gm BOD_5 / m^2 / day
- (2-6) sets of discs are installed in series in the operation line so that length of each set reaches to 7 meter.

4- Activated Sludge Tanks

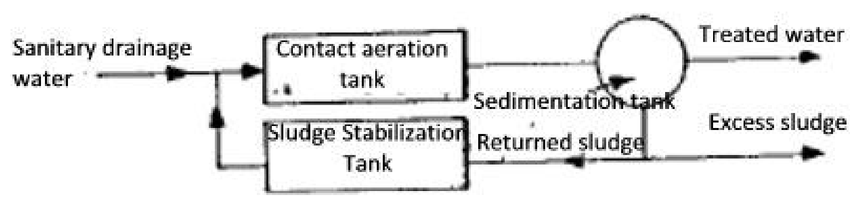
- Aerobic bacteria is the activated bacteria in the biological treatment because this bacteria are considered a good oxidizer for organic materials as well as they can be collected in the form of viscous flocks, which are the main factor in purification processes by activated sludge. Fig (2-12)



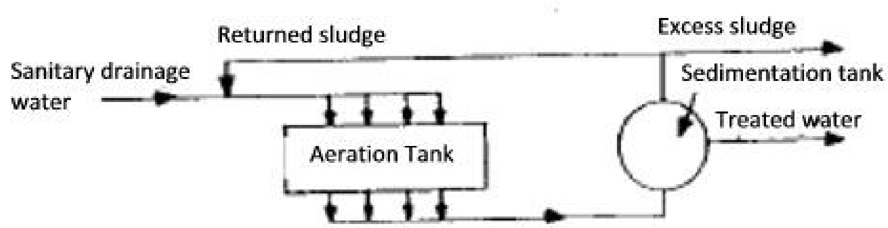
Conventional activated sludge system



Step supply system



Contact Stabilization System



Completed Mixed System

Fig (2-12): Activated Sludge Process

4-1 Operation Systems

4-1-1 Conventional System

- Sludge activating tank is supplied by sanitary drainage water and returned sludge at the inlet of the tank, where it is aerated equally and the activated sludge exits from the tank outlet.
- Disadvantage of the conventional system is the great size of the aeration tank in addition to unstable operation in case of increase hydraulic and organic load rates that affects treatment efficiency.

4-1-2 Tapered Aeration System

In this system, air is pumped in high rates at tank inlet to provide the necessary amount of oxygen in this area then gradually decreased along the tank, which increases efficiency of oxidization process.

4-1-3 Step Aeration System

In this system, air is pumped in steps along the path of aeration tank to provide the necessary amount of oxygen in different areas of aeration tank to increase efficiency of aeration process.

4-1-4 Completed Mixed System

- Aeration tank is supplied by raw sanitary drainage water equally along tank length and the water is sucked from the tank with the same method from the other side.

- This system is characterized by accommodation of great amounts of suspended solid materials in the aeration tank, where this leads to significant decrease in tank size, in addition that this system is stable to the greatest extend to face any increase in hydraulic or organic pumping rates.

4-1-5 Contact Stabilization System

- Contact stabilization system is defined as bio-absorption process. This system may contain or not contain primary sedimentation stage. Sanitary drainage water with the returned sludge are aerated in contact aeration tank for short period ranges from 0.5 to 1.5 hours by completion absorption process of organic materials exist in sanitary drainage water by sludge. This is followed by sludge sedimentation process in final sedimentation tank, then it is sucked and pumped to an aeration tank called sludge stabilization tank for a period ranges from 3 to 6 hours before being pumped to contact aeration tank again.
- This system requires an amount of air similar to the conventional system. This amount is distributed to contact aeration tank and sludge stabilization tank, however total volume of contact aeration tank and sludge stabilization tank is equal to half volume of aeration tank in conventional system.

4-1-6 Extended Aeration System

- This system is similar to completed mixed system and oxidation ditch system, where sanitary drainage water is completed mixed in the aeration tank in addition to increase of aeration period.

- This system is characterized by decrease rate of organic load, long aeration time, increased amount of suspended solid materials, decrease ratio of food to amount of micro-organisms and increase removal efficiency of BOD. Due to long period of aeration, solid materials are well stabilized. Great amount of air is used in this system; therefore operation costs are very high.

4-1-7 Oxidation Ditch System

- It is a method of activated sludge methods and depends on extended aeration system. It consists of oval long channel contains three horizontal mechanical mixers or brushes to mix the water in the tank. Sides of the tank are made from reinforced or plain concrete.
- In this method, must keep continuous mixing to ensure contact of water with surface air, where oxygen required for the biological process is entered, in addition to preventing sedimentation of suspended materials.
- Water velocity at the ditch ranges from 0.3 to 0.4 m/s. Width of the ditch is determined according to suitable length of the mixer that gives the required amount of air. Depth of the ditch ranges from 1 to 1.2 meter.
- Diameter of the brush is about 70 cm, and is revolved with speed of 75 rpm to give oxygen dissolution rate of about 2.8 kg / linear meter / hour.
- Efficiency of the brushes necessary for water mixing in oxidation ditches is (120-150) m^3 of water / linear meter of the brush.
- The brushes need electrical power of 1.35 KW / linear meter of the brush. Volume of the oxidation ditch is calculated according to design criteria in table (2-1) for extended aeration system.

- Raw water is entered from the side of the ditch and move in the direction of rotation of the brushes. The water exits from the opposite side which is provided by outlet heir of suitable length, which is designed so that it is not flooded with water in case change of its level in the ditch.

4-2 Design Method

To design sanitary drainage water treatment plant using activated sludge, the following steps must be followed:

1. Equation (1) is used to determine volume of aeration tank:

Volume of aeration tank:

$$\frac{F}{M} = \frac{Q}{V} (L_i - L_e) / MLSS \text{ ----------------------------- } (1)$$

Where:

$\frac{F}{M}$ = Food to microorganism ratio

Q = Design flow m^3 / day

V = Reactor volume m^3

L_i = BOD to reactor gm / m^3

L_e = BOD required gm / m^3

$MLSS$ = Mixed liquor suspended solids gm / m^3

From column (9) in table (2-1), BOD_5 removal percentage can be determined, ratio of food to micro-organisms (F/M) can be determined from column (4), thus total amount of suspended solids in the aerator can be selected form column (2) (MLSS). By knowing the flow (Q), equation (1) is used to find volume of aeration tank (V).

2. Hydraulic retention time in aerator is fulfilled using equation (2) compared with column (5)

Hydraulic retention time in aerator:

$$T = \frac{V}{Q} \quad \text{---} \quad (2)$$

$$T = (Li - Le) / {}^{F}\!/_{M} \quad * \ MLss$$

3. Organic load rate is calculated by comparison this value with column (6).

4. Excess sludge is calculated using equation (3)

Excess sludge production:

$$\frac{M_W}{F} = a - b / {}^{F}\!/_{M}$$

$$M_w = aF - bM \quad \text{---} \quad (3)$$

Where:

Mw = Excess solids produced (kg / day)

F = BOD removed = Q (Li - Le) (gm / day)

(a) constant = 0.7

(b) - constant = 0.075

5. Sludge retention time (SRT) is calculated from equation (4) and then comparing the results with column (7)

Sludge retention time (SRT)

$$SRT = \frac{\text{Total MLSS in aerator}}{\text{Excess sludge produced}} = \frac{M}{M_W}$$

$$SRT = \frac{M}{aF - bM}$$

Recirculation rate of sludge (R)

$$C2R = C1\ (R+Q)$$

C1 = MLSS in reactor gm/m^3

C2 = MLSS in returned sludge gm/m^3
= 10000 gm/ m^3 (max)

R = return sludge 100% of Q m^3/hr.

Q = flow rate m^3/hr.

C2 = mg/lit

SVI or sludge volume index

Volume in liter for one gram of activated sludge after settlement period of half an hour in one liter size cylinder =

$$\frac{\text{m/ settled sludge * 1000}}{\text{mg/lit suspended solids (MLSS)}}$$

6- Recirculation rate of sludge is calculated from equation (5) and the result is compared with column (8).

Oxygen requirement

$$O_c = [a\,F / M + b^I]\,M \quad \text{---------------} \quad (6)$$

a = constant 0.55 for domastic wastewater

b = constant 0.15 for domastic wastewater

7- Quantity of the required oxygen is calculated from equation (6) for total oxidation of the organic materials (for carbonation and nitrification)

(7) For nitrification

$$O_{nit} = 4.6\,Q\,(\ NH3) / 10^3 \quad \text{---------------} \quad (7)$$

O_{nit} = Qxygen required for nitrifiation

= 4.6 kg of O_2 for NH_3 to N03

NH3 = (Inf NH_3 as N - Effluent NH_3 as N) gm / m^3

= NH3 gm / m^3

DO = dissolved oxygen (1 - 2) gm / m^3

= 2.0 kg O2 / kg BOD removed for extended

= (0.9 - 1.2) kg O2 / kg BOD Removed for conventional

Sanitary Drainage Water Treatment System Design

Treatment System	Hydraulic properties of water flow (1)	MLSS Mg/liter (2)	Ratio of volatile suspended solids to MILSS (3)	F/M BOD Kg/kg/day (4)	Hydraulic retention time (Hour) (5)	Organic load rate BOD Kg/m^3 (6)	Solids retention time (day) (7)	Ratio of returned sludge to raw water flow (8)	BOD removal percentage (9)	BOD removed kg (10)	Air amount required for each kg of BOD (11)
Conventional	Compressed	1500-3000	0.8	0.2-0.4	4-8	0.3-0.7	5-15	0.25-0.5	85-95	0.8-1.1	40-60
Tapered aeration	Compressed	1500-3000	0.8	0.2-0.4	4-8	0.3-0.8	5-15	0.25-0.5	85-95	0.7-1.0	50-80
Step aeration	Compressed	2000-3000	0.8	0.2-0.4	3-5	0.7-1.0	5-15	0.25-0.75	85-95	0.7-1.0	50-80
Contact stabilization	Compressed	1000-3000 (1) 2000-6000 (2)	0.8	0.2-0.5	0.5-1.5 (1) 3-6 (2)	1.0-1.2	5-15	0.25-1	85-95	0.7-1.0	50-80 (2)
Completed mixed	Compressed	3000-6000	0.8	0.2-0.6	3-5	0.8-2.0	5-15	0.25-1.0	85-95	0.7-1.0	50-80
High rate aeration	Compressed	300-800	0.8	1.5-0.5	1.5-3	1.2-2.4	0.2-0.5	0.15-0.5	60-75	0.4-0.6	25-50
Extended aeration and oxidation ditch	Compressed	3000-8000	0.6-0.5	0.5-1.5	18-36	0.2-0.4	20.-30	0.35	90-98	-1.0	100-140

(1) Contact aeration tank (2) Sludge stabilization tank (3) This amount is divided equally over the contact aeration tank and sludge stabilization tank.

Table no. (2-1) Design amendments in various operating systems for activated sludge process

5- Final sedimentation tanks

5-1 Purpose of the unit

- Sedimentation of the suspended solids formed in filters or sludge activation tanks.

Sedimentation tanks are divided into two types:

A. Rectangular tanks

B. Circular tanks

  - It is preferred to use circular tanks due to the high flow entering to final sedimentation tanks.

5-2 Unit Components

- As in primary sedimentation tanks.

5-3 Design criteria

5-3-1 Rectangular tanks:

- Length: 25- 40 m
- Width: 6- 10 m
- Water depth: 3.00 – 3.5 m
- Retention time: 1.5 – 2.00 hour

- Surface load rate:

A- Final sedimentation tank after biological filter

Surface load rate = 10 – 25 m^3 / day / m^2 in case of medium flow

= 40 – 50 m^3 / day / m^2 in case of maximum flow

Load rate at outlet heir: 100 – 150 / day / linear meter

B- Final sedimentation tank after sludge activation tank (Does not contain extended aeration system)

Water depth = 3.5 – 4.5 m

Retention time = 2.0 – 3.0 hour

Surface load rate = 25 – 35 m^3 / day / m^2 in case of medium flow

= 40 – 50 m^3 / day / m^2 in case of maximum flow

Load rate at outlet heir: 100 – 150 / day / linear meter

5-3-2 Circular tanks:

- Water width: 2.5 – 4.5 m
- Diameter: 25 – 40 m
- Bottom inclination: 1/10 – 1/15
- Surface load rate: As in rectangular tanks
- Load rate at outlet heir: As in rectangular tanks
- Retention time: As in rectangular tanks
- Surface load by suspended solids must be confirmed using the following formula:

$$\text{Loading by suspended solids (kg /m}^2\text{/hour)} = \frac{\text{MLSS (mg / liter)}}{\text{Surface load rate (m/hour)} \ (24 \times 10^3)}$$

Suspended solids load rate:

- 3 in case of medium flow
- 8 in case of maximum flow

Third: Sludge Treatment

Sludge treatment passes through three stages:

1 Thickening

2 Stabilization

3 Dewatering

1- Thickening

The purpose of this process is to decrease water content in sludge and increase concentration of solids, which leads to decrease total volume of sludge before stabilization and dewatering processes. This helps in decreasing cost of stabilization process, if any. The used methods are as follows:

1-1 Gravity thickeners

In these tanks, arms are used to slow mixing of sludge that leads to water separation and increase of sludge concentration at the lower part of the tank because of sludge density is greater than water density. Water is dewatered at the upper part of the tank and returned to the inlet of the plant. Fig (2-13) shows mechanical sludge thickener.

1-1-1 Design criteria of gravity thickeners

- **Retention time:**

1 – 2 day, it is taken 1.5 day and depends on sludge volume ration (SVR)

- **Surface load rate:**

- Sludge collected from primary sedimentation tanks: (98 -147) kg solids /m^2/day
- Sludge collected from final sedimentation tanks after biological contact filters:

(49 -59) kg solids /m^2/day

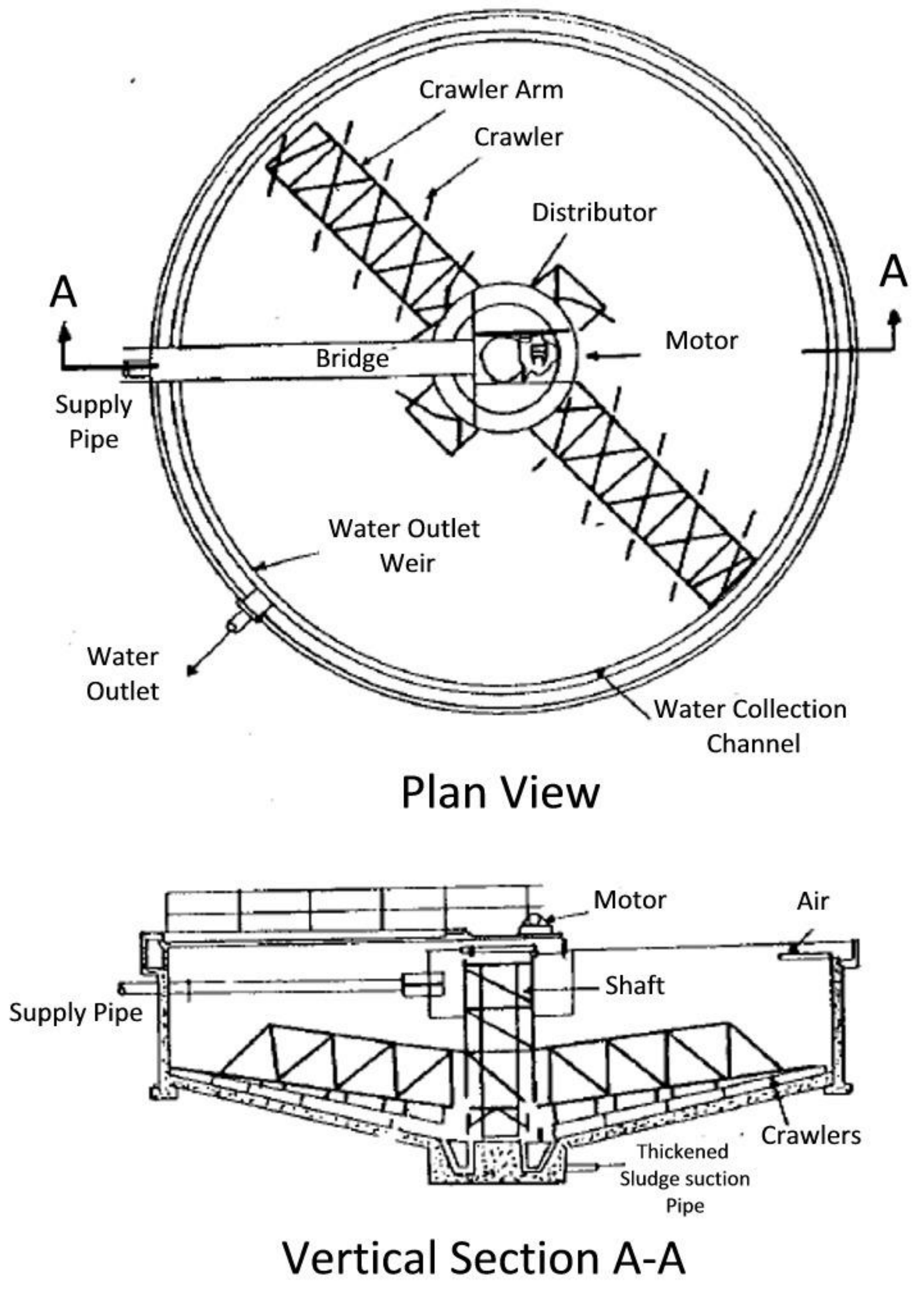


Fig (2-13): Mechanical Sludge Thickeners

- Sludge collected from final sedimentation tanks after activated sludge tanks: (20 -30) kg solids /m^2/day
- Sludge collected from primary sedimentation tanks + Sludge collected from final sedimentation tanks after activated sludge tanks: (49 -59) kg solids /m^2/day

- Arms rotation speed: It is selected so that the linear velocity at the tank circumstance does not exceed 3 m/min
- Water width: (2.5 – 3.5) m
- Tank floor inclination: 1/6 or 1/4
- Diameter of sludge suction pipe: Not less than 150 mm.

1-2 Air floatation thickeners

This type of thickener is used in big treatment plans and produce great amount of sludge. Air bubbles are used in these tanks with certain volume. Fig (2-14) shows steps of operation of air floatation system.

1-2-1 Design Criteria

- Use of compressed air subjects part of sludge to pressure ranges from 3 to 5 kg/cm^2.

The following must be taken into consideration:

- Water from pressure chamber must be mixed with the raw sludge before being entered to air floatation thickeners.

- After entering sludge to floatation thickeners and due to sludge pressure relief, the suspended solids are floated due to their saturation with air and their volume weight is decreased and formation of floated sludge that are collected using a system for scum collection as shown in the attached drawing.

- Operation efficiency of air floatation system can be improved by adding chemical materials, such as aluminum sulfate and polymers that assist in increasing efficiency of solids separation, which reaches to 90-98%.

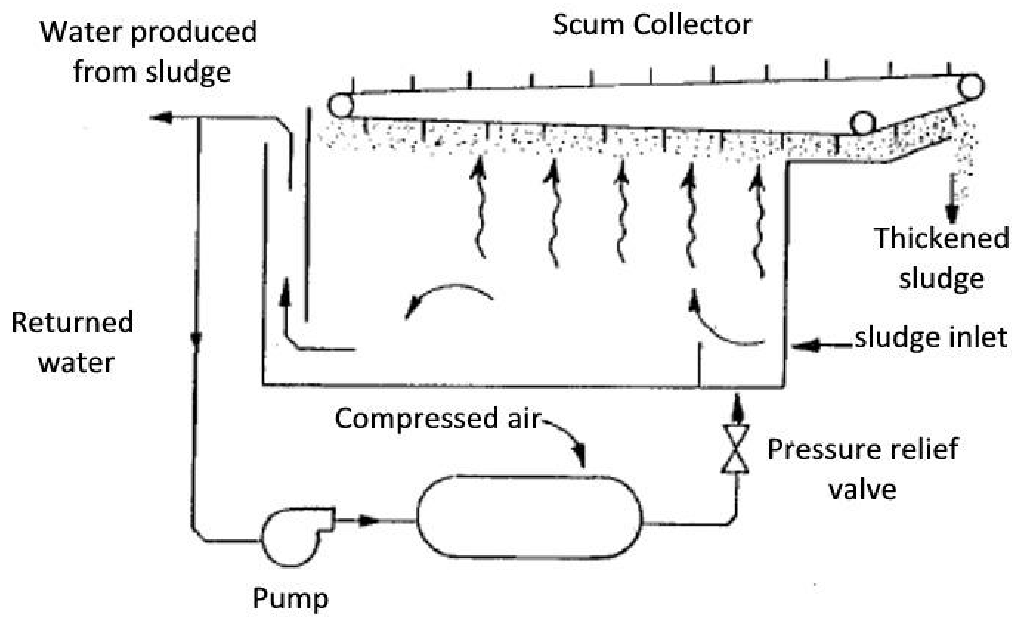


Fig (2-14): Air Floatation Sludge Thickeners

2- Anaerobic stabilization (Anaerobic Digestion)

Anaerobic digestion process is defined as the process of stabilization and oxidation of organic materials in sludge in the absence of oxygen. During digestion process, solid organic materials are collected and converted into gases. From this group of reactions stabilized sludge is produced with high concentration of inorganic materials. Not all organic materials are stabilized during reaction processes due to the presence of complex organic materials that are hard to be decomposed.

There are two types of digesters:

2-1 Conventional sludge digester

In this type of digester, sludge is not mixed in the digester and the following layers are produced:

- Surface clarified water layer.
- Activated digested sludge layer
- Digested sludge layer.

Fig (2-15) shows conventional sludge digester.

2-1-1 Design Criteria

Digester volume is calculated from the following equation:

$$V = V_f - {}^{2}/_{3}\ (V_f - V_{c_1})\ T_l$$

Where:

V = Digester volume (m^3)

V_f = Daily added sludge volume (m^3/day)

V_{c1} = Daily sucked sludge volume (m^3/day)

T_l = Digestion time from 20-25 (day)

Sludge can be digested in one stage system and the following values are used to confirm calculations of digester volume:

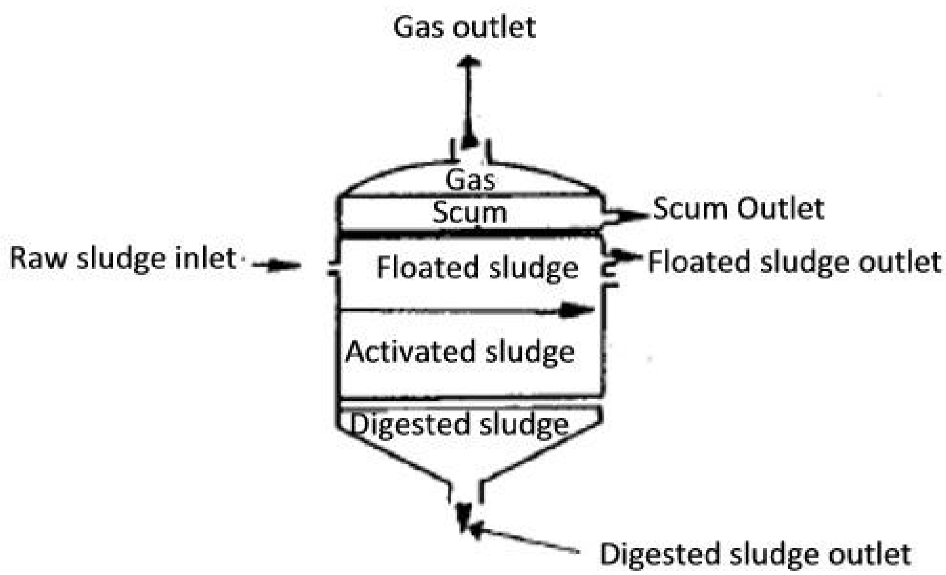


Fig (2-15): Conventional Sludge Digester

The proposed volume:

A. Sludge from primary sedimentation tanks: 0.05 – 0.075 m^3

B. Mixture of primary and biological sludge: 0.1 – 0.15 m^3

Load factor:

- Sludge from primary sedimentation tanks or sludge collected from primary and final sedimentation tanks: 0.3 – 0.75 kg / m^3 / day

2-2 High rate sludge digester

Sludge is added continuously to high rate digester and well mixed by mechanical methods or by returning part of the gas produced from digestion process after being compressed. The digester is heated to operate with maximum efficiency in the presence of physophilic bacteria (10-40°C).

Fig (2-16) shows high rate sludge digester.

Due to continuous mixing of digester contents, different layers are vanished in the digester, such as:

- Surface water layer.
- Inactivated sludge layer.

Retention time can be significantly decreased through sludge condensation and to increase percentage of solids to 6%. In this case retention time is decreased to (10-15) days.

Fig (2-17) shows two stages high rate digester, where the design allows for each stage to accommodate the sludge produced from flow of 20,000 m^3/day from raw water.

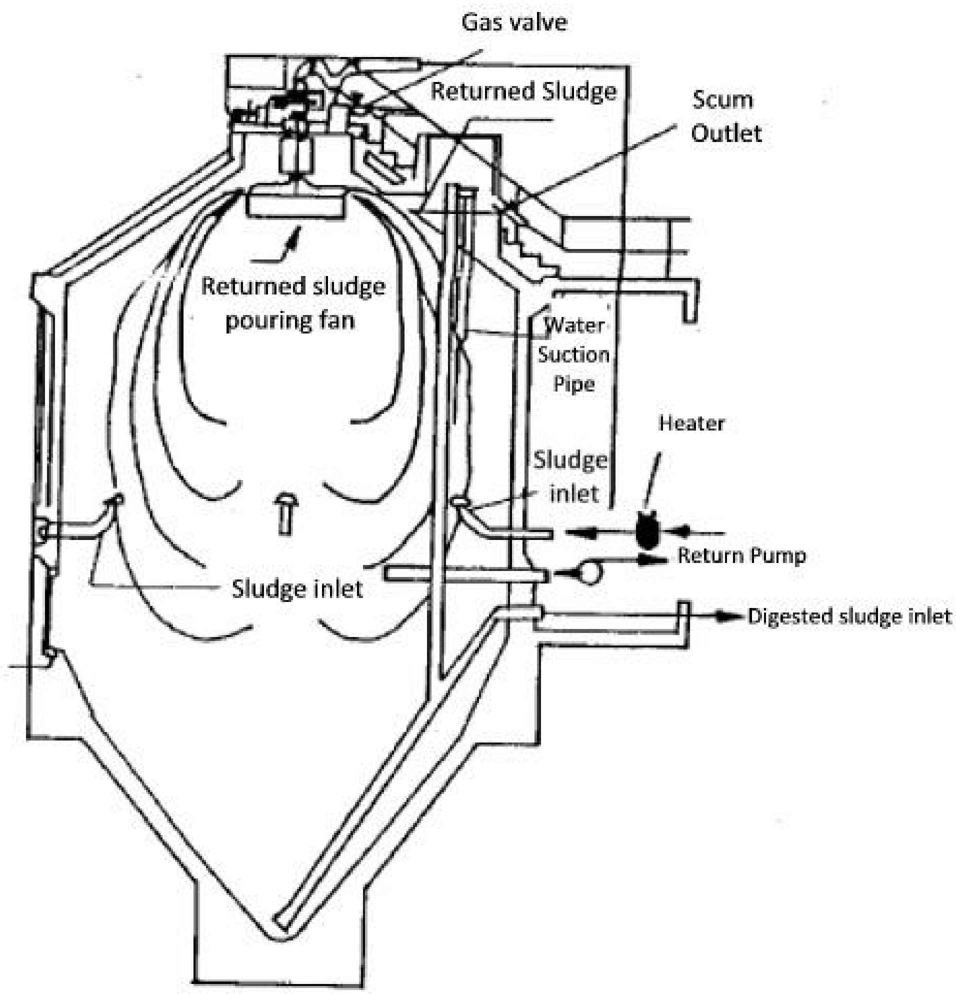


Fig (2-16): High rate sludge digester components

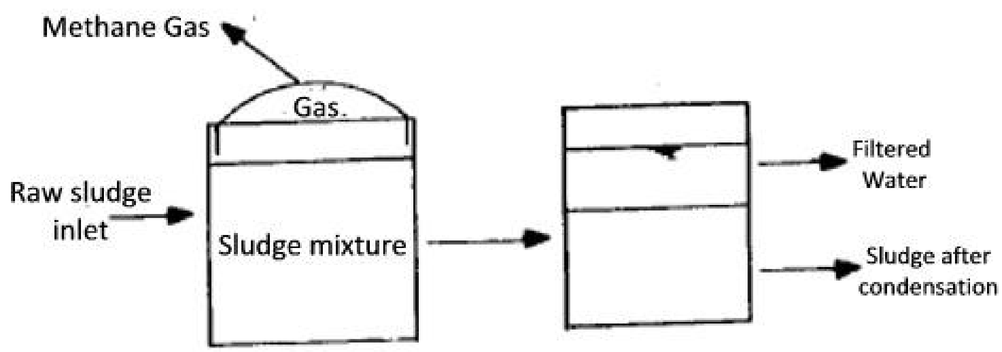


Fig (2-17): Two stages anaerobic sludge digester

2-2-1 Design Criteria

Digester volume:

$$V1 = V_f \cdot T_h.$$
$$V11 = V_f + {}^2/_3\ (V_f - V_d)\ T.$$

Where:

V_I = First stage digester volume (m^3)

V_{II} = Second stage digester volume (m^3)

V_f = Daily added sludge volume (m^3/day)

V_d = Daily calculated sludge volume (m^3/day)

T = Second stage retention time (usually about 10 days)

T_h = Retention time in first stage digester (10-15 days)

Circular conventional digester with diameters range form 6 to 55 m is used in treatment plants with capacity 4000 m^3/day and less, while treatment plants of capacity more than 4000 m^3/day are provided with two digesters each of one stage and has a capacity that allows treatment of sludge produced from 3000 m^3/day of raw water at most.

High rate sludge digester is designed in two stages; each stage accommodates the sludge produced from flow 20,000 m^3/day of raw water.

- Water depth ranges from 4.5-6 m and must not exceed 9 m. Digester height over water surface to tank cover is determined by knowing the following:

- Shape and type of tank cover.
- Maximum pressure collected over water surface.

This height in the tanks covered by fixed covers of conical surfaces is greater than 0.4 m, while for movable covers, the minimum allowable height between water surface and the cover is greater than 0.6 m. For tanks with fixed horizontal surface, this height is about 0.8 m, as shown in Fig (2-18).

- Gas daily production rate is about 0.9 m^3/day of the decomposed volatile organic materials.
- Digester bottom is design in inclination shape with inclination ratio not less than 1:12 to facilitate sludge suction.
- Digester cover is designed in a fixed shape from reinforced concrete in the form of dome, cone or flat surface. While the movable cover is made from steel and must allow for the cover to move a distance from 1.2-2 m. The produced gas is sucked from outlet holes installed at 1 m from water surface. Digester cover is provided with a number of maintenance holes, not less than two holes, with diameter not less than 0.75 m to facilitate maintenance works.
- For big digestion tanks of diameter exceeds 25 m, they are provided with four maintenance holes at least. These holes are used to separate the floated scum.
- Sludge transfer pipes diameter is not less than 200 mm, and sludge velocity in the pipes ranges from 1.5 to 2.5 m/s.
- Gas pipes are made from cast iron, galvanized iron or galvanized steel. Pipes are tied by flanges if pipe diameter is greater than 100 mm. For pipe diameter less than 100 mm, pipes are welded. Underground pipes are tied by mechanical joints.

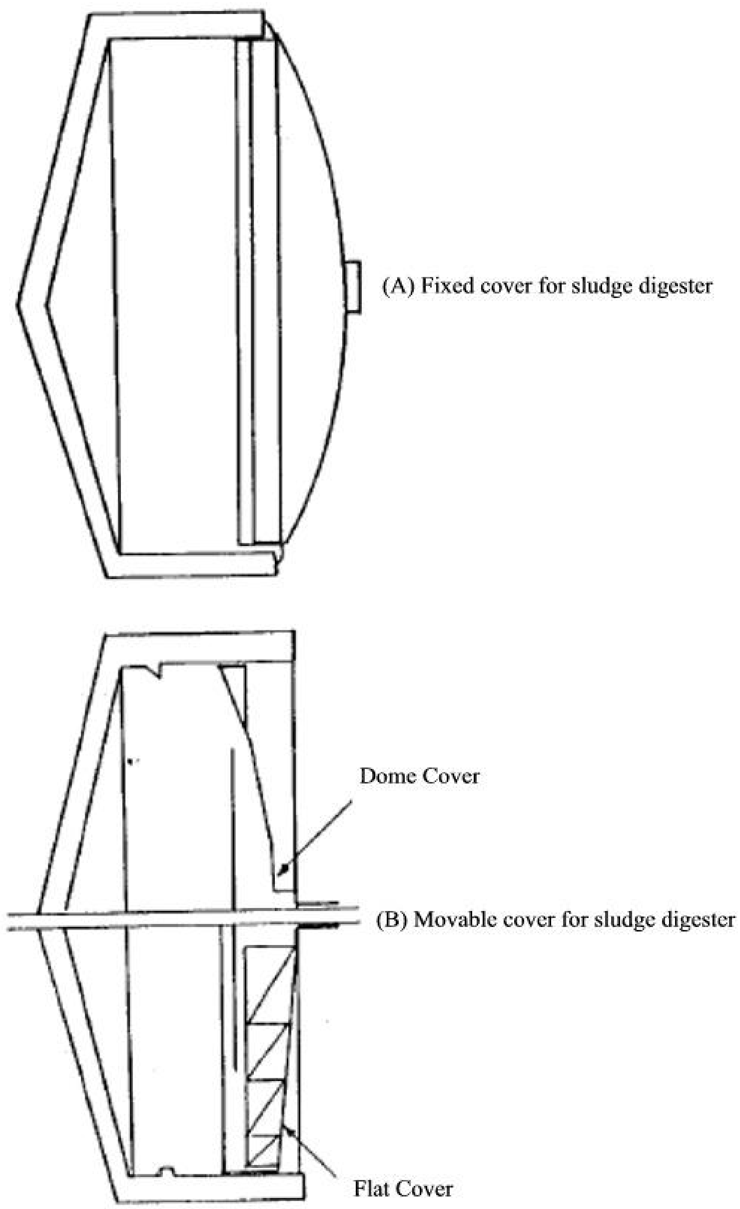


Fig (2-18): Foxed and movable cover of sludge digester

2-3 Aerobic sludge digesters

It is applied usually when using activated sludge system in the biological treatment (using of mixed sludge form primary and final sedimentation tanks or the sludge resulted from final sedimentation tanks only), but it is hard to use this system for digestion of the sludge resulted from primary sedimentation tanks only. It is used also in digestion process with compressed aeration system. Fig (2-19) shows aeration sludge digester.

2-3-1 Deign criteria

- Surface load rate: 4-6 m^3/ m^2 / day
- Sludge depth in the tank: 3-6 m
- Retention time:

10-12 day at 20°C.

20-30 day at 10°C.

- Quantity of volatile organic materials that will be stabilized = 35-45 %
- BOD = 1.7-1.9 gm/ gm oxygen / gm of stabilized organic materials
- Rate of power used for air generation = 21-32 KW / m^3 (treated sludge)
- Oxygen concentration in digester contents = 1-2 mg / liter.

3- Sludge dewatering

Digested sludge contains water reaches to about 90% and solids 10%, therefore other methods are used to separate large amount of water to increase sludge thickening.

Sand tanks are used as a method for sludge dewatering. Existence of oils and greases affect efficiency of this process. In case of unavailability of an area necessary for construction of dewatering tanks, sludge must be prepared chemically and thermally, and then water is separated using mechanical methods, such as air vacuum filters and centrifuge system.

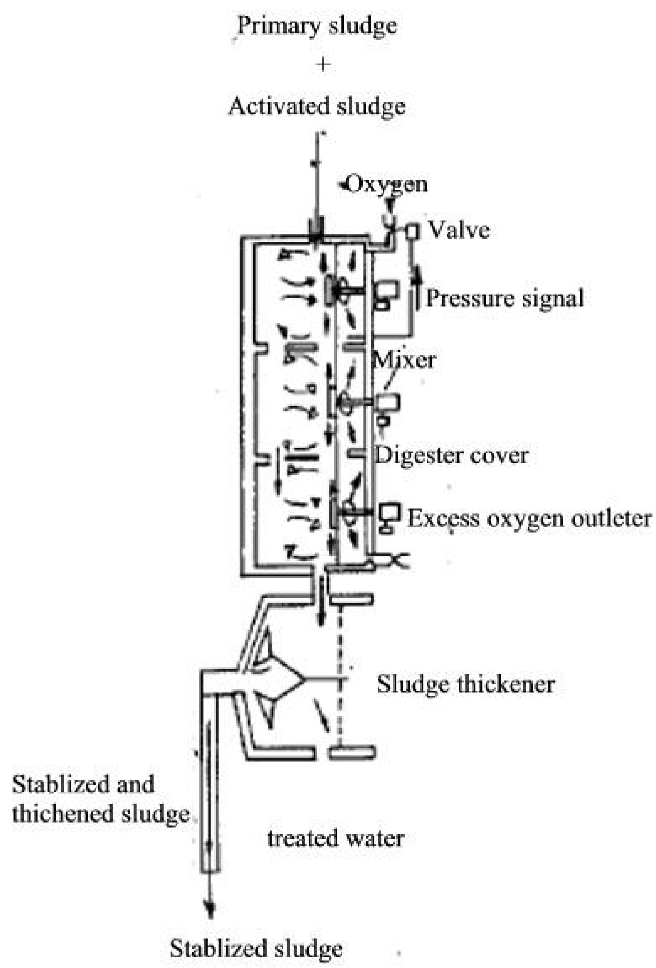


Fig (2-19): Digester for activated sludge treated with sludge aerobic stabilization

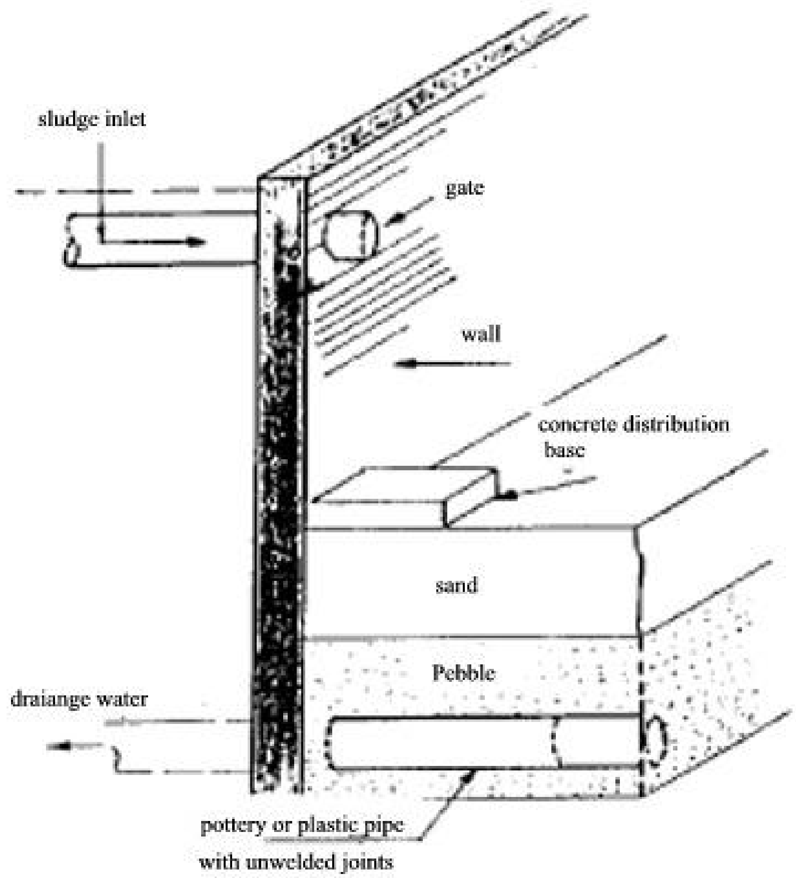
Climate conditions around the country are appropriate for thickeners system that can be operated economically when the land is available for construction.

3-1 Sludge dewatering beds

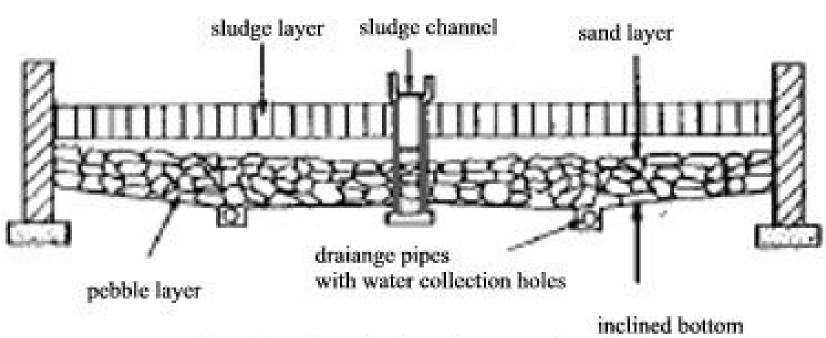
In this method sludge are dewatered by flooding method, where sludge is distributed to beds contain layer of pebbles and sand and the water in the sludge leak through the sand layer in addition to evaporation. Fig (2-20) shows sludge dewatering beds.

3-1-1 Unit Components

- Pebbles layer: Its depth ranges from 15 to 30 cm. Pebbles are of equal size ranges from 3 to 6 mm and are distributed over water drainage network at height not more than 15 cm for each layer.
- Sand layer: Sand layer must be clean with average granules size ranges form 0.5 -0.75 mm. Depth of sand layer ranges form 15 to 30 cm. Upper surface of sand layer must be leveled.
- Drainage network: Drainage network is constructed form pottery or plastic pipes without welding the joints, with diameter ranges form 100 to 150 mm. These pipes are installed at spacing not more than 6 m.
- Bed walls: Bed walls are constructed form bricks or concrete of height not less than 40 cm over sand surface.
- Beds bottom: Beds bottom is constructed form layer of plain concrete when infiltration water is near from beds surface level. If infiltration water is far from beds surface, impermeable soil layer is laid at the bottom of the beds.



A- Sludge dewatering bed View



Section in sludge dewatering bed

Fig (2-20): Sludge Dewatering Beds

3-1-2 Design Criteria

- Thickness of each sludge layer ranges from 10-15 cm
- Retention time (time period for sludge layer before being flooded with other layer is 4 days)
- Area of dewatering beds is taken double the design area for dewatering and discharge of the beds.
- Roads are constructed between beds for discharge works and sludge loading.
- Drainage water:

Drainage water must be returned to primary sedimentation tanks.

3-2 Mechanical dewatering

When using mechanical equipments for sludge dewatering, polymer or chemical coagulants must be used.

Many methods are used, such as:

1. Vacuum sludge filters.
2. Pressing sludge filters.
3. Centrifugal device.

3-2-1 Belt pressing filters

It consists from rotating cylinder installed on it filtration medium (belt) made from any of the following materials:

- Wool- Fibers- Felt- Industrial Fibers- Plastic
- Stainless steel network.
- Rolls of stainless steel springs

In addition to the following parts:

- Air vacuum pumps.
- Treated water pumps
- Moisture traps.
- Treated water tank.
- Conveyer for sludge transfer after dewatering.
- Pipes and valves network for sludge and treated water transfer.

3-2-1-1 Design criteria

A- Filtration rate:

- 10 kg/ m^2 / hour for separation of digested sludge.
- 50 kg/ m^2 / hour for separation of sludge in primary sedimentation tanks.

Usually it is used filtration rate equal 15 kg/ m^2 / hour.

B- Cylinder speed:

- (7-40) revolution / hour
- Vacuum pressure = 500-650 mm mercury
- Operation hours:
  - 30 hour/ week in small treatment plants ‹ 5000 m^3 / day
  - 20 hour/ week in big treatment plants.
- Moisture percentage in treated sludge:

- 80% in raw sludge.
- 70% in digested sludge from primary sedimentation tanks.

Fig (2-21) shows air vacuum sludge filter

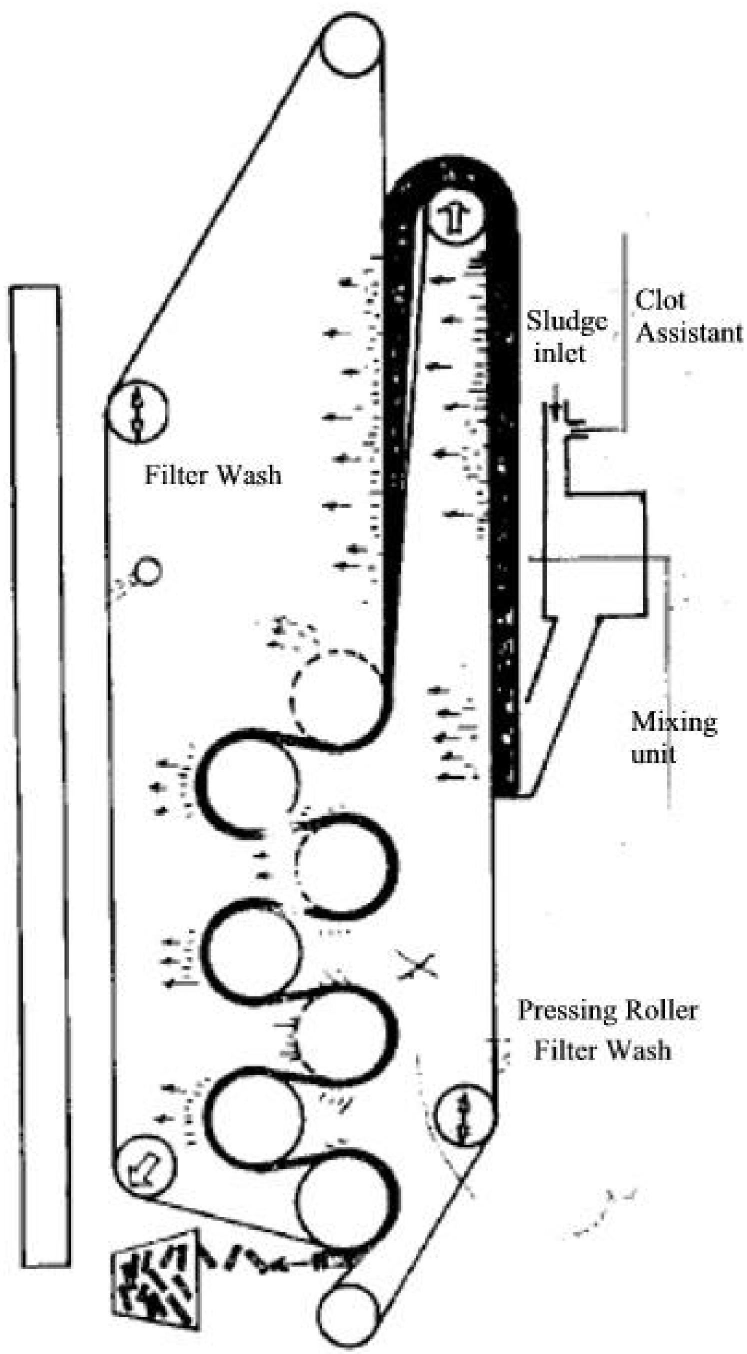


Fig (2-21): Air Vacuum Sludge filter

3-2-2 Sludge pressing filter

3-2-2-1 Unit Components

Pressing filter contains set of square metal plates empty from inside. Pieces of filtration fabric are installed between the plates. Sludge is put in the gaps between the plates and filtration fabric.

3-2-2-2 Design Criteria

- The filter operates under pressure ranges from 4 to 12 kg / cm^2
- Operation period from 1 to 3 hour
- Moisture percentage after filtration = 55-70%

Fig (2-22) shows sludge pressing filter

3-2-3 Centrifuge device

Centrifuge device is used efficiently to reduce moisture percentage in sludge to 70%. Treated water from centrifuge devices contains high percentage of solids more than the solids in the treated water from the dewatering beds.

Return of treated water from centrifuge system to primary treatment units leads to increase of suspended solids in primary sedimentation tanks and consequently causes increase of its concentration in the treated water.

Fig (2-23) shows mechanical dewatering using centrifugal forces.

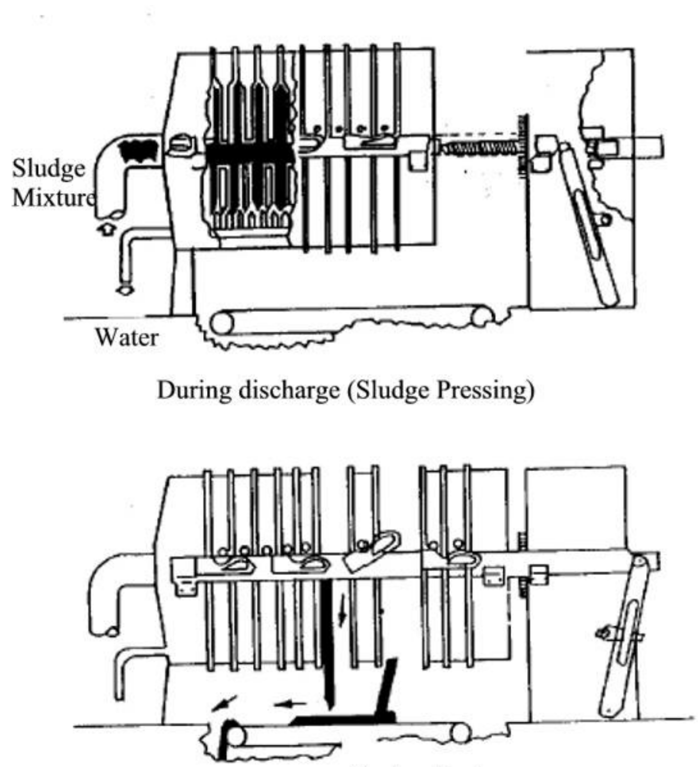


Fig (2-22): Sludge Filter Press

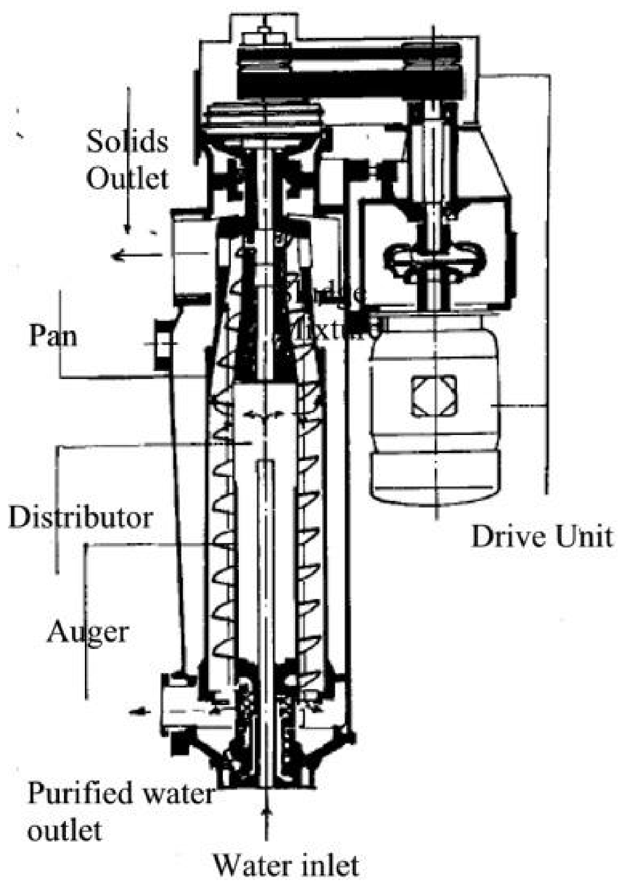


Fig (2-23): Sludge thickening systems using centrifugal forces

Fourth: Oxidation Ponds

1- Purpose of the unit

Liquid wastes are treated in these ponds by a natural method depends on common activity of algae and bacteria in the presence of sunrays and using of some elements already exist in the liquid wastes, where aerobic bacteria use the oxygen dissolved in water for oxidation of organic materials. This oxidation produces stabilized organic materials and carbon dioxide. Algae in turns use carbon dioxide with some slats for photosynthesis in the presence of sunrays and give oxygen which is of bacteria needs.

That means both algae and bacteria give to each other what they need. Bacteria activity is maximized at surface layers of water exposed to sunrays. These layers have great concentrations of dissolved oxygen during day light, while at nigh algae activity is reversed and start to consume the dissolved oxygen in water and give carbon dioxide, which leads to decrease or vanish of dissolved oxygen in water.

Organic materials are stabilized by aerobic and anaerobic reactions together. In upper layers subjected to penetration of sunrays, algae can be activated and give oxygen dissolved in water to be used by aerobic bacteria in stabilization of organic materials. While the lower layers of the ponds, which are not subjected to sunrays, there is an area for sedimentation of the suspended materials and in it anaerobic reactions are activated for stabilization of organic materials in these sediments.

Therefore, organic materials are stabilized in the surface layers only, but proportion of these materials is stabilized by anaerobic bacteria.

Surface layer rich with oxygen plays an important role, in addition to aerobic oxidation of organic materials, which is control of anaerobic reactions wastes occur at the bottom, such as bad gases and organic acids.

2- Anaerobic Ponds

They do not depend on algae and are constructed before aerobic and anaerobic ponds to decrease concentration of BOD consumed by a percentage ranges between 50 and 70% and water depth from 2 to 4 m, and is selected 3m. The effective factor in design of these ponds is the temperature. Retention time in the ponds ranges from 3 to 5 days, and is taken 3 days to prevent conversion of the ponds to facultative ponds. In these ponds aerobic bacteria activity will be increased. By decomposing of organic materials at the bottom, methane gas and carbon dioxide are produced, which assist in moving and mixing of sediments, but these gases hold the sediments to ponds surface that may be escaped with the water coming out from the ponds. Also, a layer of floated materials is formed at pond surface and is a source of flies and bad odors.

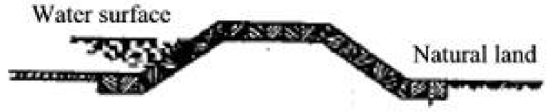
3- Facultative Ponds

These ponds are constructed at depth ranges between 1 and 2 m, and is selected usually 1.5 m, with a great area allows for retention of water for many days during which organic materials are oxidized by microorganisms and assisted by algae cells that supply oxygen to upper layers of water using sunrays, which is called Photosynthesis.

Organic materials are converted by bacteria to stabilized inorganic materials and algae cells exit with treated water. They are called facultative ponds because solid sediments are sediment in the lower layers that lie under effect of anaerobic activity, while the upper layers lie under effect of aerobic activity, where sunrays reach to these layers and the algae grow and give dissolved oxygen in this area.

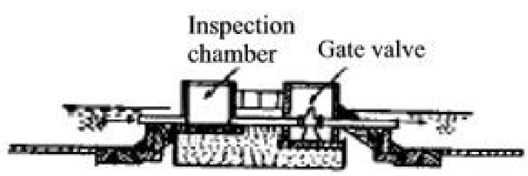
4- Maturation Ponds

These ponds are used to improve bacteriological and chemical properties of wastes, especially harm bacteria and viruses exist in the liquid wastes. Water depth ranges from 1 – 1.5 m, where rate of removal of harm bacteria is greater at smaller depth due to sun activity and retention time of about 7 days. They are consisting of three units; retention time in each unit is two days.

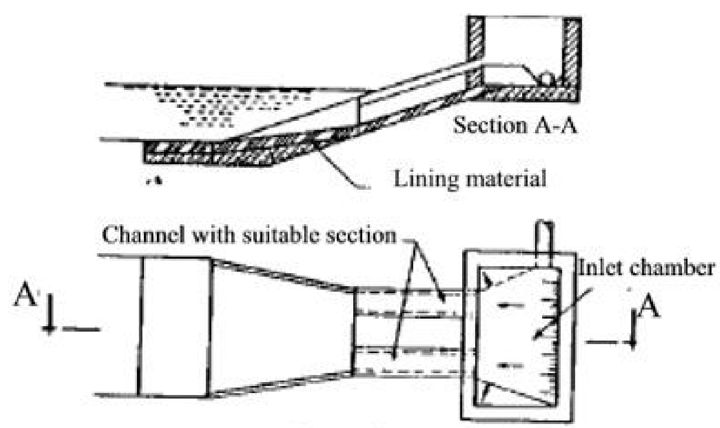


Section in external bridge

Section in internal bridge



Connection between ponds



Plan View
Inlet for big ponds

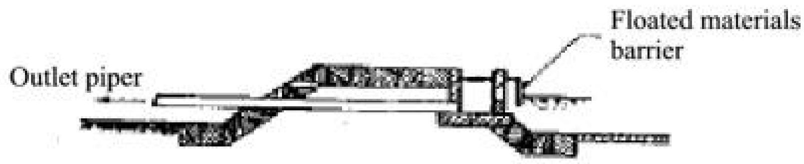


Fig (2-24): Oxidation ponds

5- Components and design criteria of oxidation ponds

5-1 Anaerobic ponds

- Retention time in anaerobic ponds ranges from 3 to 5 days.
- Organic materials (BOD_5) removal rate:

  1.00 day 50%

  2.50 day 60%

  5.00 days 70%

These percentages of removal are taken at average temperature of water in the pond.

- Water depth in anaerobic ponds ranges from 2.50 to 5.00 m at temperature greater than 20°C and depends on area of the available land. An additional depth must be added for sediments.
- Organic load (BOD_5) ranges from 0.125 kg /m^3/day to 0.3 kg /m^3/day.
- In case of increase organic load (BOD_5) to 0.40 kg /m^3/day, bad odors appear.
- Sediments collection rate ranges from 0.03 m^3/person/year to 0.04 m3/person/year.
- Anaerobic ponds must be discharged from sediments when the depth of these sediments reaches about half depth of the pond.

- Ratio of length to width of the pond ranges from 2:1 to 3:1.

- Anaerobic ponds sides or bridges must be inclined by 1.5, 2.00, 3.00 or 4.00 to 1.00 and concrete slab must be constructed at the sides over the surface of the water to resist motion of water by winds and prevention of herbs and graces growth and existence of mosquito.
- The sides are lined with polyethylene plates, rubbles, plain concrete or concrete slabs.
- The bottom is lined if the experiments proved that soil particles are coarse. In normal case, the solids block soil pores.

If necessary, the bottom is lined by the following:

- 10 cm of compressed clay.
- Polyethylene or vinyl plates
- Mixture of sludge and cement.

- Bridges are higher than water surface by about 1.00 m to resist water motion by winds.
- In case of existence of heirs between the ponds, heir width is about 3.00 m.

5-2 Facultative Ponds

- They are aerobic and anaerobic oxidation ponds.
- Length to width of the pond ranges from 2:1 to 3:1

- Water depth in facultative pond ranges from 1.50 to 2.00 m
- Organic load (BOD_5) ranges from 200 to 300 kg / hectare /day.

- Area $= \dfrac{Q \times t}{D}$

Where : Q = Flow in m^3 / day

t = Retention time in days

D = Depth of water in Pond (m)

- <u>Asian Institute of Technology Method</u>

$$Ls = 8 \times 1.054^{T} \qquad (1)$$

Ls = permissible load of B.O.D_5 kg/hectare / day

T = temperature in (F^o)

$$t = 10 \times D \frac{Li}{Ls} \qquad (11)$$

Where :

t = detention time in days

Li = influent B.O.D. mg/litre

Ls = allowed B.O.D. load kg/hectare

D = depth of water in pond in metres

Another Modified Formula :

$$t = \frac{Li - 60}{18 \times 1.05^{T-20}}$$

where :

Li = Influent B.O.D. mg/litre

T = Temperature in (^{o}C)

60 = 60 mg/litre, the allowed B.O.D. in effluent

Design Based on Mean Temperature of Coldest Month :

$$1 - A = \frac{Q\,(Li - Le)}{18D\,(1.05)^{T-20}}$$

Where :

A = Area in m^2

Q = m^3 Per day

Li = B.O.D5 of incoming liquor in mg/litre

Le = B.O.D_5 effluent

T = Mean temperature of coldest month in ^oC

D = depth of water in pond in metres

2- Empirical Method:

$$A = \frac{Li \times Q}{2T - 12}$$

Where :

A = area m^2

Li = B.O.d_5 mg/litre

Q = daily flow m3/day

T = temperature in (^oF)

(average of coldest month)

3- Indian method :

$$\lambda s = 375 - 6.25\ L$$

Where :

λs = Load in Kg/hectare

L = Latitude of the place in degrees

Temperature		T by (1) 1 st Formula	T by (II 2nd Foemula
^oC	^oF		
15	59	27	24
20	68	17	19
25	77	10	15

5-3 Maturation Ponds

- Maturation ponds are used to remove pathogens such as some germs, fungi, protozoa and viruses. They must be used when using the waste water coming from the ponds in irrigation.
- If all ponds are equal in size and retention times, which are occur in most cases, maturation ponds are designed using the following equation:

$$\frac{N_I}{N_E} = \frac{1}{(kR + 1)^n}$$

Where:

N_I = Germ number in the internal flows

N_f = Germ number in the external flows after retention time in days.

K = Vanish or removal constant of micro-organisms / day

R = retention time in days

n = Number of ponds in series.

Selection of values of design factors for maturation ponds

N_I = Fecal Coliform number which depends on it mainly in design of maturation design in internal flows is estimated by 4.2×10^8 E- Coli / 100 mm, while coliform removal in anaerobic ponds is negligible. Removal percentage in maturation ponds is 99%, and the evaporation is 10% of water volume in the maturation ponds and remains 90%. Therefore, E-coli in the first pond of maturation ponds is calculated as follows:

$4.2 \times 10^{10} \times (0.99\text{-}1)/0.9 = 4.7 \times 10^6$ E- Coli / 100 mm

N_I is taken 4.7×10^6 E- Coli / 100 mm

NE: It is taken less than 2×10^3 E- Coli / 100 mm

It depends on studying reuse of the waste water coming from the ponds.

K' : If Fecal Coliform is the base for the design, vanish constant is taken = 2.00 This factor depends on the temperature and this value will be taken when designing the ponds at T-20°C. When temperature is changed, the following equation is applied:

$$\text{Temperature factor (T-20°C)} = \frac{\text{Vanish constant at T°C}}{\text{Vanish constant at 20°C}}$$

$$\frac{K'_T}{K'_{20}} = \theta\ (T - 20)$$

$\theta = 1.07$

R: Retention time in days, and it is taken between 3 and 10 days, in case of one pond, retention time must not less than 5 days.

After selecting the above design factors, values for number of ponds in series are specified. The number of ponds is selected in a way that achieve the germ number in the external flows after retention time of less than 2×10^3 E- Coli / 100 mm

Pond volume is calculated by multiplying retention time by the flow. Number of ponds is repeated in series according to the selected number of ponds.

Note:

1 Water depth in maturation ponds is taken 1 m.

2 Germ number in the internal flows = 4.7×10^6 E- Coli / 100 mm

Germ number in the external flows = 2×10^3 E- Coli / 100 mm

R and n are selected according to the following table:

n	1	2	3	4	5
R (day)	1175	23.7	6.15	2.98	1.96

2- Mechanical Design

2- Mechanical Design

2-1 Mechanical Screens

Purpose of mechanical screens is the removal of suspended materials from the liquid wastes. They must be continuously cleaned by passing the liquid wastes through bars with certain spacing according to hydraulic design of screen channels, where the bars block these impurities and remove them outside screens duct using mechanical system.

A mechanical screen consists of frame installed inside filtration channel and contains blocking bars. At the top of the bars mechanical system is installed to operate cleaning rake that removes periodically the impurities blocked at the bars according to method of operation of screens, whether by using time periods adjusted by timer or by control the levels in front and rear of the screens.

2-1-1 Design criteria

There are important factors must be taken into consideration before selecting type and design of the mechanical screens:

- Determine depth and width of filtration duct and maximum water level inside the duct.
- Determine flow rates coming to the screens (peak flows)
- Determine operation and stop levels of the screens.

Type of the used screens is determined according to bars position and depth of filtration duct.

2-1-2 Types of mechanical screens

Mechanical screens used in the treatment plants are divided into two main types:

1- Vertical bar screens, used in deep filtration channels

2- Curved bar screens, used in medium and small depth filtration channels.

The above two types are branched into many types according to system of motion of cleaning set.

2-1-3 Mechanical and electrical design of screens

2-1-3-1 The following conditions must be provided when designing the mechanical screens:

- All moving parts must be over maximum water level in filtration channel within 30-50 cm except deep vertical screens with continuous motion of scraper which are used at inlet of pumping stations.
- Screen rake is operated under hydraulic push or spring force to ensure holding of the rake inside the bars during operation.
- Screen bars have fixed spacing (determined according to hydraulic design) and the distances are hold between them inside the frame for easy assembly and disassembly of these bars as one part.
- Rated power for drive unit of cleaning set must be greater than the power necessary for drive the set (calculated) with not less than 50%.
- Protection degree for drive set must not less than IP 65 (against weather conditions).
- Screens are provided with the protection means necessary for safe operation including:

• Torque limiting device operated in case of rake overload.

- Motion is separated automatically from the drive unit in case of existence of obstacle at cleaning set by reversing direction of motion.

- Linear velocity of cleaning rake must not exceed 0.05 m/s

2-1-3-2 The following requirements must be fulfilled when manufacturing mechanical screen equipments:

- Adjustment of cleaning rake in vertical and horizontal directions.
- Matching rake teeth profile with the screen bars to ensure engagement during operation.
- Automatic cleaning of the rake at the end of cleaning stroke using wiper.

- Existence of chute to receive the falling wastes from the rake and removed them to collection tank or conveyor belt.
- Motion of drive unit is transferred to cleaning rake through interlock (link) using track or pins and not metal ropes.
- Cleaning rake teeth must be designed in a way that make them penetrate inside the bars to ensure removal of the collected impurities in each stroke for cleaning (length of the tooth must not less than 50 mm)
- Cleaning rake must be provided by axial motion that enables it to overcome any accumulation of wastes and allows pushing unusual amounts of impurities in stages.

2-1-3-3 Mechanical screen components are made from the following materials:

1- Cleaning rake, sprockets, track, guide, all screws, nuts, bars, wiper and the slider are made from stainless steel with degree determined according to type of liquid wastes and their chemical analysis.

2- Covers of the moving parts are made from stainless steel plates with thickness not less than 4 mm.

3- Outer frame of the screens, connection arms and their structure are made from galvanized steel sections or treated with suitable surface paints determined by the designer.

4- In case of using conveyor belts, their materials are subject to the same conditions.

2-2 Equipments of sand disposal tanks

2-2-1 Purpose of equipments of sand disposal tanks

It is used for sweeping, collecting and removing of the sediment sands at the bottom of sand sediment channels, where sands are removed after being washed and filtered from water.

Sands are collected by mechanical system differs according to tanks design. There are two main types:

A. Circular tanks: The mechanical system consists of mixer for making cyclone motion in the tanks that pushes the sands to the bottom of the tank, where they are sucked and removed.

B. Longitudinal tanks: The mechanical system consists of movable bridge holds lower sweeper for sweeping sediment sands at the bottom in the direction of the collection well, and then sands are sucked by sand pumps or by valves system for disposal.

In the two systems, the compressed air generated by air compressors may be used to control velocity of water inside the tanks by making spiral motion to remove the sands from the suspended organic materials (oils and greases).

2-2-2 Design criteria

The following factors must be taken into consideration when design sand removal disposal tank equipments:

- Depth, width and water level of sand channel
- Flows coming to sand separation channel (peak flows)
- Expected quantity of sands to calculate capacity, dimensions and method of suction of sand from the bottom, whether by pipes and valves system or by lifting pumps.

- Type of sand separation tanks (circular of longitudinal)

2-2-3 Design Conditions

The following conditions must be taken into consideration when design sand separation tank equipments:

- Sweeper bridge is designed at a load of 500 kg /m^2 in addition to operation requirements (loads resulted from the equipments installed on the bridge)
- The two carriages of the bridge (in case of longitudinal tanks) are drove by independent electrical motors for each carriage electrically connected to be operated and stopped together or by one motor for both carriages through torsion bar for motion transfer to both carriages.
- Lower sweepers must be adjusted according to inclination of channels bottom. These sweepers are operated to collect the sands efficiently from all area of tank floor and push it to collection well at the end of the tank in case of longitudinal tanks and to center of tank in case of circular tanks.

- Active motion of the sweeper is done during forward motion of the carriage in the direction of collection well (in case of longitudinal tanks) and the sweeper is raised automatically from channels bottom during return stroke.
- Sand separation channels are provided with adjustable heirs and barrier for scum and floated oils.
- The sweeper is provided with control panel of type resistant to weather conditions installed outside the buildings provided with the necessary protections against overload and short circuit.
- Sweepers are operated automatically by timer determines time and duration of operation (10-15 minutes) over the day, and the bridge, in case of longitudinal tanks, is provided with direction reverser to reverse direction of motion when reaching to end of sweeping stroke.

In addition, operation can be performed manually and the sweeper stops by itself at the end of complete operation cycle (go and fro).

- The sweeper is supplied by electrical current through suspended flexible cable carried on supports along bridge side or by cable reel electrically operated and linked with bridge motion (spring is not allowed).
- Operation of sand lift pumps (if used) must be linked with motion of Sweeper Bridge, as the pumps are operated automatically when the sweeper reaches to two third of sweeping stroke.
- Sand separation equipments must be provided with active means for washing the collected sands after being lift from the tanks and a removal means from the water exists with the sand (see the appendix)
- When using compressed air in aerated grit chambers, amount and air pressure required from the air compressors must be determined by the hydraulic designer. It is recommended that tanks air inlet pipes are separately connected

with the main line coming from the compressors to be removed from the channels for maintenance works and then returned without stop operation of other channels.

2-2-4 Manufacture Requirements

The following requirements must be taken into consideration when design sand separation channel equipments:

- Sweeper Bridge is provided with 2 transition trolleys, each with four wheels, two of them are linked with motion of the drive unit and the other two follow them. These wheels are covered with anti-friction material.
- Bridge walkway width must not less than 750 mm.

- The bridge is provided at the two sides by handrail made from galvanized steel or aluminum sections of height not less than 1 m. The sections are connected with stanchions, and not by welding. Handrail is installed on bridge body by tying screws.
- Sweeper Bridge is provided with guide wheels at the two sides of the channels to prevent slipping at any of the two directions in the horizontal plane.
- Lower sweeper blades are provided with replaceable rubber strips with thickness not less than 8 mm. They are installed on the edge of sweeper blade by removable steel bar. Strips can be adjusted to decrease their wear.
- Sweeper Bridge is provided with upper crawler for sweeping the floated grease. It is installed at the side of the tank. It is provided also by rubber strips.
- The bridges are provided with foot anti-slipper at the both sides of the walkway with a height not less than 100 mm.

2-2-5 Sand separation tank equipments are manufactured form the following materials:

- Metal frame of sweeper bridge and suspension arms are made from carbon steel and treated against weather conditions or using hot galvanization.
- Lower and upper sweepers are made from galvanized steel plates with thickness not less than 4 mm and galvanization layer not less than 250 micron.
- Outlet heirs and scum barrier are made from stainless steel and its degree is determined according to chemical analysis of liquid wastes.
- All screws, nuts, pins, adjusting and fixing strips are made from stainless steel and its degree is determined according to operation conditions.

2-3 Sedimentation tank equipments

Purpose of sedimentation tank equipments is to sweep, collect and suck solids sediment and collected at the bottom of the tanks. These sediments are collected by lower suspended sweepers which sweep sedimentation tank bottom, either by circular motion in circular sedimentation tanks or by linear motion in rectangular sedimentation tanks. The collected sediments (sludge) are sucked by pipes installed at bottom of the tank ended with valves to control amount of sludge coming out from the tank.

In sedimentation tanks oils and grease are floated and swept using the upper sweepers which collect the floated materials (floated scum) in a collection funnel ended with pipe pours in sediments well.

Sedimentation tank equipments are composed mainly from fixed or movable bridge holds crawlers provided with lower and upper sweepers, where the crawlers are operated by central drive, in case of fixed bridge, or by peripheral drive in case of movable bridge, for circular tanks, or by linear motion of the bridge for rectangular tanks.

Flight type crawlers are also used and installed on movable track by drive unit installed at the beginning and the end of sedimentation tank for rectangular tanks.

Sedimentation tank equipments include also heirs to adjust level of water coming out from the tanks in addition to inlet valves, sludge suction pipes, control and protection means for operation of crawlers and valves.

2-3-1 Design criteria

2-3-1-1 When performing the design, the following factors must be taken into consideration:

- Determine tanks diameter (in case of circular tanks) or dimensions (in case of rectangular tanks) as well as tanks depth, maximum height of water inside the tanks and their floor inclination.
- Determine flows coming to the tanks.
- Determine levels of water coming out from the tanks.
- Determine amounts of the produced sludge and its method of suction (Intermittent or continuous).

2-3-2 Types of sedimentation tanks

Sedimentation tanks are divided into two types:

- Circular tanks: They are divided in turn into tanks with fixed or movable bridges.
- Rectangular tanks: They are provided with suspended crawlers installed on movable bridge, or flight crawlers installed on track moved by drive set installed on the tanks.

2-3-3 Design conditions

- Live load of crawler bridge must not less than 250 kg / m^2

- Lower sweepers must be designed in a way that allows sweeping of the sediment sludge at the bottom of the tank in each cycle of the crawler in the direction of the collection space.
- Crawler suspension arms must be fixed by hinges that allow free swinging of these arms to be customized with the motion of the lower sweepers at the bottom of the tank to compensate irregularity that may exist at the floor of the tank.
- Floated scum collection box (funnel) must be of automatic motion with the upper sweeper to allow exit of suitable amount of water with the scum for flushing of funnel and outlet pipe.
- Crawler drive set must be from type resists weather conditions with protection degree IP65.

- Linear velocity of the crawler bridge transition trolley (in case of movable bridges) must be within 0.03 to 0.05 m/s.
- Crawler bridge walkway width must not less than 600 mm
- Lower or upper sweeper blade height must not less than 300 mm.
- Outlet heirs must be adjustable in the vertical direction within + 50 mm and are manufactured in saw tooth (V) shape.
- Bridges and crawlers are provided with control panel contains protection means against over load with protection degree IP65 (resistant to weather conditions).

2-3-4 Manufacture requirements

The following requirements must be taken into consideration when manufacturing sedimentation tank equipments:

- Lower sweepers are carried on rotating wheels made from neoprene or polyethylene and are operated on stainless steel axis so that the sweeper is loaded in front of the wheels.

  These wheels are installed on crawler arms by tying screws. In some cases, the sweepers are installed directly on the suspension arms (by tying screws also) so that the sweepers are operated under their weight.

- Lower sweepers are provided with natural or artificial acids anti-resistant rubber with thickness not less than 8mm and installed on edge of the sweeper blade by tying screws provided with steel strip for fixing.
- Tanks are provided with set of rotating brushes suspended from Crawler Bridge for cleaning of outlet heirs and outlet channel. These brushes are rotated electrically and manufactured from wear- high resistant material.
- Crawler bridges are provided with handrails along the bridge of height not less than 1 m over walkway level.

- Crawler bridges are provided with foot anti-slipper at the both sides of the walkway with a height not less than 100 mm
- Handrails are installed on the main structure of the crawler bridge by tying screws and not by welding.
- Outlet heirs are firmly sealed against water leakage by using rubber strips between them and tank walls of thickness not less than 4 mm.
- Primary sedimentation tanks are provided with scum board installed at 500 mm from tank edge. Height of the board is not less than 300 mm with adjustable level in the vertical direction within + 75 mm.
- In case of circular sedimentation tanks, movable crawler bridge is installed axially at the center of the tank using axial bearing able to absorb shocks

resulted from irregular horizontal level of bridge transition trolley at the edge of the tank and the curvature occurs at the bridge structure itself within 1.5 degree.

- Axial bearing of Crawler Bridge (in case of movable bridge) must be completely sealed against penetration of dusts, impurities and water.
- Drive set of Crawler Bridge is supplied with electrical current through closed type slip rings carried on the central axis of the bridge in case of circular tanks, and through cable reel loaded on the bridge and provided with drive motor linked with bridge motion to extend and store the electrical cable with go and fro motion of the bridge in case of rectangular tanks.
- Valves set used in suction of sludge from the tanks are composed of gate valve, hydrostatic telescopic valve and flow valve in series.

2-3-5 Sedimentation tank equipments are manufactured form the following materials:

- Metal frame of Crawler Bridge, suspension arms, handrails and walkways are made from high quality steel treated against weather conditions using suitable paints or hot galvanization.
- Lower and upper sweepers are made from galvanized steel plates with thickness not less than 4 mm and galvanization layer not less than 250 micron.
- Outlet heirs and scum barriers are made from stainless steel of thickness not less than 4mm, or from high quality aluminum of thickness not less than 6 mm according to designer requirements and chemical analysis of liquid wastes.
- All screws, nuts, pins, adjusting and fixing strips are made from stainless steel and its degree and type are determined according to operation conditions.

2-4 Surface Aerator Equipments (Surface Aerator Units)

Purpose of surface aerators units is to provide liquid wastes in aeration tanks with the required oxygen according to the amounts specified in the design calculations of these tanks through mixing of the atmospheric air that contacts the surface with these liquids by causing rotational motion on the surface of the liquid that suck the air inside the liquid, at the same time, turbine fan of the aerators is operated as a pump to spread the liquid at a level higher than upper surface level, where a contact occurs between liquid particles and the surrounding atmospheric air that leads to absorption of oxygen. Amount of the added oxygen is controlled by change flooding level of these turbines.

2-4-1 Surface Aerator Equipments

Surface aerators are consist mainly from turbine opened impeller which causes mixing and pumping of the liquid wastes through rotational motion taken from electrical motors connected with it by speed reducers to reach to the rated speed. These equipments include also heirs that control liquid level inside the aerators which are operated manually or automatically to lower or raise liquid surface level and hence level of flooding aerator turbines.

2-4-2 When performing the design, the following factors must be taken into consideration:

- Liquid wastes flow
- Organic load
- Amount of air (oxygen) required to be added according to type of the required treatment.
- Number of surface aerator in each tank
- Dimensions of the aerators.

2-4-3 Design Conditions

When designing surface aerator equipments, the following conditions must be taken into consideration:

- The aeration must provide good mixing for tank contents and complete distribution of oxygen through liquid wastes in the tank by the following:
- Ratio between fan turbine diameter of aeration unit and width of the aerator must be within 5:7.
- Specific power must not less than 40 W for each cubic meter of liquid wastes volume in the tank.
- Turbines must be of low speed type (the speed must not exceed 60 l/m)
- Water eddy velocity at any point in the take must not less than 0.3 m/s.

- Turbine is consists of impeller in the shape of inverted cone with radial blades with central bass extends across the cone to the edge. The impeller can be shaped in the form of pipes that pumps the water from inside to outside the turbine.
- The turbine (entire rotor) must be statistically and dynamically balanced to ensure smooth operation and avoid damage of aerator bearing.

2-4-4 Manufacture requirements

The following requirements must be taken into consideration when manufacturing the aerators:

- The aerators must be provided with level adjustment devices for leveling of the unit.
- The impeller must be linked with the drive shaft by coupling using flanges fixed with enough number of screws according to torque calculation of the set.
- The drive shaft must be with suitable section to transfer the required power without causing waves or vibrations during operation.

- Speed reducers (gearbox) must be of helical gears type designed for vertical loading.
- The gearbox is operated inside oil bath and supported by stub shafts on ball bearings.
- Thrust bearing must be of enough capacity to hold turbine weight in addition to any hydraulic load resulted from the operation, and in this purpose it is used journal/ thrust bearing or taper rollers.
- The gearbox must resists weather conditions and provided with oil level probe, discharge plug, vent pipe and glass level indicator.

- All gears and ball bearings must be designed for life span not less than 100,000 hour and can be operated for 24 hours continuously under tropical conditions. Service factor of the gearbox must not less than double motor power.
- The aerators are rotated by high torque electrical motor completely sealed and cooled with fan (TEFC) of protection degree IP55.
- Motor power must be of 30% at least more than the maximum absorbed power on the turbine shaft at its complete flood.
- Dimensions of the outlet heirs are designed in a way that allows maximum flow and control of water level inside the aerator.
- Heirs are operated electrically (with the possibility of manual operation) and are provided with position indicator. The heir is operated automatically through level control according to the signal received from measuring poles of the oxygen dissolved at the outlet end of the tank.

- Aerators control panels must be of weather conditions-resistant type and must be provided with protection means against overload and short circuit.
- The aerators must be provided with emergency stop buttons of latch-off type installed on the aerators.

2-4-5 Surface aerator equipments must be manufactured from the following materials:

- All steel parts used in aerator equipments must be treated and painted with material resistant to corrosion and anti-liquid wastes impact partially septic.

- Turbine drive shaft is made from stainless steel with degree and type suitable to be used with raw water according to chemical analysis.
- Gears and axes in the gearbox are made from hardened high tensile steel.
- Enclosure of gearbox is made from cast iron.
- Aerator outlet heirs are made from stainless steel with degree determined according to chemical analysis.
- All screws and nuts are made from stainless steel or it is allowed to use galvanized screws on the parts flooded in water.

2-5 Sludge Thickener Equipments

2-5-1 Purpose of sludge thickener equipments

The purpose is to separate the water from the solids (sludge) by assisting them to sediment vertically, sweep and collect thickened sludge sediment at the bottom of the thickener, where it is sucked through pipes and valves system to collection chamber and then to sludge treatment place.

Due to the nature and type of the thickened sludge produced from these thickeners, which tend to quick clot, adhesion and cause blockage in the carrying pipes, its paths must be shortened as possible in case of using nature gravity pipe lines. It is recommended to use positive displacement pumps to raise it to sludge treatment places. Water and thickening degree of sediment sludge are controlled by determining periods and times of suction of thickened sludge.

2-5-2 Sludge thickener equipments

Fixed bridge made from concrete forming element of the concrete structure of the thickener or steel sections that are supported on thickener edges. The bridge is supported by set of fixed vertical arms and another movable set connected with the drive center in the thickener for mixing and sweeping, where it is moved by central drive from drive unit consists of electrical motor, reducer (gearbox) and central drive axis. Sludge thickener equipments include heirs to adjust and control outlet level of water separated from sediments (supernatant) in addition to inlet and outlet valves, control and protection devices.

2-5-3 When designing the mechanical equipments of the thickener, the following factors must be taken into consideration:

- Thickener dimensions.
- Retention time
- Active volume of the thickener.

- Quantities of incoming flows.
- Solids rate on thickener surface area.

2-5-4 Design conditions

- Sludge thickener bridges (in case of steel bridges) are constructed from suitable carbon steel sections to cover entire diameter of the thickener (complete bridge) and are designed to carry regular load of 250 kg / m^2 in addition to operation requirements of these bridges.
- Raking and scraping mechanism installed under the bridge by rotary ball joints.
- Drive set is provided with protection against overload.

- The central shaft is installed by flanges in central drive unit and rotary ball device of the bridge in the form of rotating internal cylinder.
- Power of drive unit closed anti-weather conditions type motor exceeds 50% of the required power to drive crawler set.
- Bridge drive unit installed at center of the bridge and contains sealed gearbox with cast iron enclosure. The bridge is drove by one or two drive units according to mechanical design of the central axis.
- The drive unit is supplied with electric current by ground cables.

2-5-5 Manufacture requirements

- Width of bridge walkway must not less than 750 mm and covered with grill.
- The bridge is provided with double handrail at both sides assembled by joints (and not by welding) with suitable sections.
- Height of the handrail must not less than 1100 mm over walkway level.
- The two ends of the handrail are connected with bridge structure with tying screws and not by welding.
- Lower (floor) crawler blades are provided with replaceable adjustable rubber strips of thickness not less than 8 mm. The strips are installed at about 40 mm from crawler blade edge by steel bar fixed with screws and not by welding or pressing.
- Control and stop unit is installed on the bridge (to disconnect the power supply) to be used in emergency cases of anti-weather conditions type.

- Outlet heir is made in the shape of V-notched gear and provided with rubber leakage seal strips of thickness not less than 4 mm. The unit must prevent leakage of water between the unit and the concrete surface.
- Outlet heir is able to be adjusted vertically within $\pm$ 35 mm from the reference level.
- Thickeners are provided by a system for cleaning the heirs and outlet channel consists of electrical or spring loaded breeches.

2-5-6 Manufacture materials

- Bridge metal structure, drive arms and central shaft are made from carbon steel treated against weather conditions according to the approved standard specifications.
- Floor sweepers and mixing arms are made from galvanized steel with galvanization thickness not less than 250 micron.
- Outlet heirs are made from stainless steel plates of thickness not less than 4 mm with degree determined according to chemical analysis of the wastes in the thickeners.
- All screws, nuts, pins, adjusting and fixing strips are made from stainless steel with degree and type suitable for operation conditions.

2-6 Screw return pumps

2-6-1 Purpose of using screw return pumps

It is used to return the activated sludge produced from final sedimentation tanks to the aerators or primary sedimentation tanks.

The reason of using screw pumps because they are characterized rather than other types of pumps by the ability to customize the flows coming out from them with the change of water level in suction sump.

The screw pump consists of:

Helical winding installed on empty cylinder, and this composition is known as the screw. An upper and lower side of the screw is installed on bearings and is drove by electrical motor and reducer.

2-6-2 When manufacturing these pumps, the following conditions must be taken into consideration:

- The blades forming the screw are made from steel plates welded on an empty central cylinder. Outer edge of these blades is shaped to match size and shape of the cylindrical core.
- Ends of the central cylinder are provided with water sealed plates with protrusions for installing the bearings.
- Upper end of the central cylinder is supported on thrust and radial ball bearing with enclosure made from cast iron. The bearing is equipped to be installed on strong concrete base.
- Lower end of the central cylinder is supported on journal bearing inside cast iron enclosure installed on swiveling trunion equipped on fixing plate installed by reinforced concrete that can be replaced without disturbing installation of the screw.

- Lower bearing is self aligned, sealed against water leakage and automatically greased using separate grease unit installed adjacent to pump drive unit.
- Screw pump is drove by electrical motor of sealed type and cooled by TEFC fan with suitable insulation for tropical regions.
- The motor is connect with reducer through flexible joint (coupling) or by V shape belt according to the used type of motor.

- The reducer consists of gearbox inside cast iron enclosure. The gears are made from high quality hardened steel. The gears are assembled in parallel with service factor not less than double motor power.
- Electrical motor power must exceed 25% of maximum consumed power of the pump.

2-7 Oxidation ditches equipment

Horizontal rotor aerators

2-7-1 Purpose of the aerators:

The purpose of the aerator is to supply oxygen to the liquid wastes in these ditches necessary for oxidation of the organic materials and provide them with the kinetic energy necessary to continue their motion in the directions specified in the design of these aerators to ensure existence of sufficient velocity not less than 0.3 m/s to prevent sedimentation of solids inside these ditches.

It consists of set of metal brushes installed on stub shaft based on bearing. The drive set consists of electrical motor and suitable reducer (40-60 rpm). The drive set and the bearings are installed rear baffle in vertical position to be protected from the spread spry resulted from motion of the rotating brushes.

2-7-2 Design conditions

- The rotating aerator contains steel pipe of high torque ended with flanges provided with pins to install mixing brush blades to ensure un-displacement or sliding of these blades when moving inside the liquid.
- Mixing brushes are formed in the shape of assembly stars installed by one pin or threaded screw and not by welding to not weaken collector pipe.
- Width of brush blades is not less than 3 inches and installed at distances of about 6 inches between their centers to not weaken collector pipe.
- Blades of each brush set are installed with the opposite blades in the other sets by tying screws. Each blade must be provided with two holes, one for fixing with the brushes set and the other for linking with the adjacent brush blades.
- Stresses resulted from rotation of mixing brush sets must be taken into consideration when designing brush blades to resist these stresses.
- Main pipe of the aerator is designed in a way that allows installing solid shaft provided with flanges as one piece with motion guide to allow easy replacement at the site. It is inserted directly without screws or welding between flanges and the shaft.
- The two ends of the pipe are based on split type pillow block bearing for the two ends of the drive unit and the rear end of the pipe.

- The bearing is installed firmly on steel base installed on strong concrete base provided with screws for level adjustment.
- The used bearing must resist any un-alignment of aerators axes within 3-5 degrees and must be provided with strap at both sides to ensure double lock of the internal screw of the axis installed on aerator drive shaft. It is also provided with water seal in case of un-alignment.
- Lubrication devices of bearings are installed in appropriate place easy to be accessed to perform inspection and lubrication works.
- Bearings must have life span not less than 100,000 hour.
- Aerator drive set consists of double axis reducer inside cast iron enclosure provided with helical gears made from high divided steel alloy with positive lubrication system. The gearbox is provided with oil seal. The unit is drove with electrical motor of sealed type cooled with TEFC fan of horizontal axis, constant speed and continuous service.

- The kinetic energy is transferred from the electrical motor to the reducer through set of hoops and (V) shape belts in the presence of protection grids to avoid contact during rotation. Aerator speed of rotation can be reduced by changing sizes of the used hoops, without puller, by using divided hoops.
- Power of electrical motor must exceed 20% of the maximum absorbed power by the aerator at maximum possible flood of the brushes.

2-7-3 Manufacture requirements

- Plates are installed on the vertical blocking concrete walls to avoid splashes and preventing any water spry to reach to service area and access path to drive set and bearings.
- These plates are provided with rubber seal to be firmly installed on the drive shaft.
- Aerator flood level indicator is installed on the oxidation ditches.
- Ditches are provided with baffles to control homogeneity inside the ditches.
- Ditches are provided with separate outlet heirs with drive hoop (and cane be drove by motor) to control water level. The heir is made from reinforced plates provided with hinges on the lower plate of the heir as pivoting. Level adjustment must be within 10 inches.
- A frame is made around the outlet weir for lining of outlet hole by stainless steel plates of thickness 0.50 inch at the lower part and of thickness 0.25 inch at the sides and are installed in the concrete with the presence of sealing rubber strips.
- Aerator control panel is provided with protection against overload and short circuit.

2-7-4 Manufacturing materials

- Mixing brush blades are made from high stress steel and treated against corrosion by the effect of liquid wastes.
- The heir is made from stainless steel plates of thickness not less than 4 mm.
- The aerator is covered by two layers of epoxy after sanding and primary coating by primer.
- Drive unit is treated against weather conditions by enamel paint.
- Drive shaft and operation hoop of outlet heir is made from high tensile steel.

- Tying screws and fixing strips are made from galvanized steel.
- Pipe axial shaft and flanges are made from ductile cast iron.

3- Design of Electrical Works

3- Design of Electrical Works

3-1 Electrical motors used in pumping stations

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

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

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

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

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

B- Motors Enclosure Protection

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

- For the motors installed directly over the pimp (Close coupled) and installed in pumps house under floor level, the used motors must be of (Flood proof) type with enclosure protection IP56.

- For motors installed outdoor and subjected to weather conditions, the used motors must be of (weather proof) type with enclosure protection IP55.

- For motors operating under water level, the used motors must be of (submersible) type with enclosure protection IP68. In this case, must specify the level at which the motor works under water level.

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

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

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

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

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

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

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

Where:

P = Absorbed power on pump drive shaft (KW)

Q = Pump flow rate (liter/sec)

H = Pump total manometric head (m)

η_T = 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.

A- Metal enclosed switchgears

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

B- Metal clad switchgears

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

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

C- Circuit Breakers

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

D- Indoor Circuit Breakers

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

E- Outdoor Circuit Breakers

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

F- Switches

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

G- Disconnectors or Isolators

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

H- Circuit Breaking

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

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

3-2-1 High Voltage Switchgear

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

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

- Vertical pull
- Horizontal pull

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

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

3-2-1-1 Interlocking & Padlocking

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

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

3-2-1-2 Types of Circuit Breakers

The common types that currently used are:

A- Oil Circuit Breaker

Is divided into:

- Bulk oil CB
- Minimum Oil CB

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

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

B- Magnetic air circuit breaker

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

C- Vacuum circuit breaker

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

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

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

D- Sulphur Hexa Fluoride CB (SF6)

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

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

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

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

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

3-2-3 Low Voltage Switchgear

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

(A) Short circuit categories.

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

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker III	SF6 CB IV
1	Connection and disconnection of inductive current	At low currents, it has the feature of quiet extinguishing of spark for many half	As the oil is a good insulator, extinguishing of the spark (electric arc) is	The breaker will disconnect regardless the value of the passing current.	Path of the current chopping depends on method of extinguishing the

		cycles which produces current chopping then voltage-surge.	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.	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.	spark, generally, of the same value as in oil CB and vacuum CB.
2	Connection and disconnection of capacitive current	Tends to recover the spark after distinguishing. It has very limited value in performing this function.	Has insulation strength for each pole enough to ensure break of the capacitive current without return of the spark	Very quick recovery of the insulation strength for the vacuum gap. This provides break without return of the spark to the capacitive currents until the full load of the rated current for the breaker.	Due to the negative electricity properties, the conduction gap is quickly re-ionized which provides break without return of the spark.
3	Mechanical aspect	The standard specifications require achievement of 1000 connection and disconnection processes at no load without affecting the breaker in addition to neglected wear degree. Regular lubrication during this period must be taken into consideration in the design.		Short stroke for connection and disconnection and low power requirements, help the designer to develop strong mechanical structure for long lifespan without performing maintenance for these CBs. Usually, 10,000 connection and disconnection processes at least are achieved without maintenance.	Power requirements are located between those of oil CBs and vacuum CBs. Most of the required power is used to extinguish the spark. This power is increased as the rated current of the CB increases. Theses CBs require maintenance at periods usually reach to 10,000 connection and disconnection processes.

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

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker III	SF6 CB IV
4	Confusion in the CB				

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

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

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker III	SF6 CB IV
	(C) Effect on CBs bases	Very small	Small	Neglected	Little

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

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

No	**Characteristics**	**Air circuit breaker I**	**Oil circuit breaker II**	**Vacuum circuit breaker III**	**SF6 CB IV**

		Rate of this procedure depends on the required performance, and it ranges from monthly service, in case of heavy duty (many connection and disconnection processes per day), to periods between 3-5 years for public supply. The oil must be replaced periodically in case of repeated use of oil CBs more than any other consideration, and the low oil types need more care especially the totally submersed types.		The number of operation processes can be recorded to determined periods of performing inspection. In case of public supply boards, replacement may be done during the lifespan of the CB, while in case of heavy duty (Daily repeated loading), replacement may be done every a number of years.	Mostly, maintenance cycle every 10 years is suitable for this type, but a visual inspection must be performed regularly. Safety measures must be taken in case of existence of existence of opening to provide the gas. Special equipments are used to do.
	(B) Post-Fault Maintenance	Usually, it is proposed to perform post-fault maintenance as soon as possible to recover the CB to its normal and safe condition.		It is not necessary to perform this maintenance, but it is preferred to inspect the CBs after operation during the normal operating period.	The same as vacuum CBs.
7	Maintenance suitable for risk environment conditions and repeated operation.	Required care and performing repeated maintenance for the CB insulator faces.	It is suitable, but always requires provision and adjustment of oil level and change of the contacts, especially in heavy duty cases. Maintenance will be repeated more in case of low oil CBs.	Features of the CB is more clear in these conditions, hence annual operation costs are less compared to the other types.	Does not need repeated maintenance, but care must be given to the mechanical parts in case of repeated operation, especially if the close power is high.

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

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker	SF6 CB IV

				III	
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.

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

No	Characteristics	Air circuit breaker I	Oil circuit breaker II	Vacuum circuit breaker III	SF6 CB IV

		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.	

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

Table (2-3): Short Circuit Categories

Short circuit categories

IEC 157-1 has two categories of short-circuit performance outlined herein

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.

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

Type of material, description of part	Temperature-rise limit (measured by thermocouple)
Contact parts in air (main, control and auxiliary contacts): copper silver or silver-faced* all other metals or sintered metals Contact parts in oil	 45°C (1) (2) 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 parts of insulating material	 15°C 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, nature and disposition of which will not be the same as those adopted for the test; a different temperature rise of terminals may result and this will have to be agreed.
(6) May be measured by thermometer.

3-2-4 Thermal rating and Enclosed rating

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

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

3-2-5 Construction of 380 v distribution switchgears

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

3-2-6 Earthing

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

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

3-2-7 Earthing Well

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

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

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

The upper part of the pipe of length 20 cm is protracted inside a cast iron box with hinged cover. The dimensions of the box is not less than 35cm $\times$ 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.

3-2-8 Calculation of short-circuit current and overload current for electrical circuits

To determine rating of the protection devices against overload and short-circuit, it is required to calculate value of overload current and short-circuit current. These value can be calculated from electrical installations code Item (6-4) and Item (6-8).

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 the Transformers

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

3-3-1 Types of the used transformers

There are two types of distribution transformers:

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

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

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

3-3-2 Common Powers of Transformers

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

3-3-3 Tappings

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

3-3-4 Transformer Windings

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

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

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

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

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

3-3-5 Transforms Performance

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

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

3-3-6 Losses in the Transformers

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

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

3-3-7 Temperature Rise

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

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

(1000 KVA)

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

* Bill = Basic insulation impulse level.

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

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

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

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

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

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

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

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

3-3-8 Loading Guide of Transformers

- The ambient temperature and service conditions can be determined for the oil transformers without occurrence of damage for windings insulation due thermal effects in case of exceeding the allowed limits. The same units can be applied in case of use of other types of cooling liquids.
- Purpose of the loading guide is to give the allowed limit under certain conditions of cooling medium temperatures and the primary loading percentage of the rating power (of normal operation position) in order that the designer can select the rating power for any new constructions.
- Determine normal cooling medium temperature (e.g. 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 (2-9) shows loading guide for the oil transformers at 20°C of cooling medium.
- By this table, overload of a transformer with certain rating power can be determined during certain period of time or determine the required rating power for a transformer with daily loading cycle through drawing a curve for the relation between K1 and K2 at different values for the loading periods (t) (Fig 2-25).

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

K_1 = initial load power as a fraction of rated power

K_2 = permissible load power as a fraction of rated power

greater than unity)

t = duration of K_2 in hours

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

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

Values of K_2 for given values of K_1 and t

	K_1 = 0.25	K_1 = 0.50	K_1 = 0.70	K_1 = 0.80	K_1 = 0.90	K_1 = 1.00
t = 0.5	+	+	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

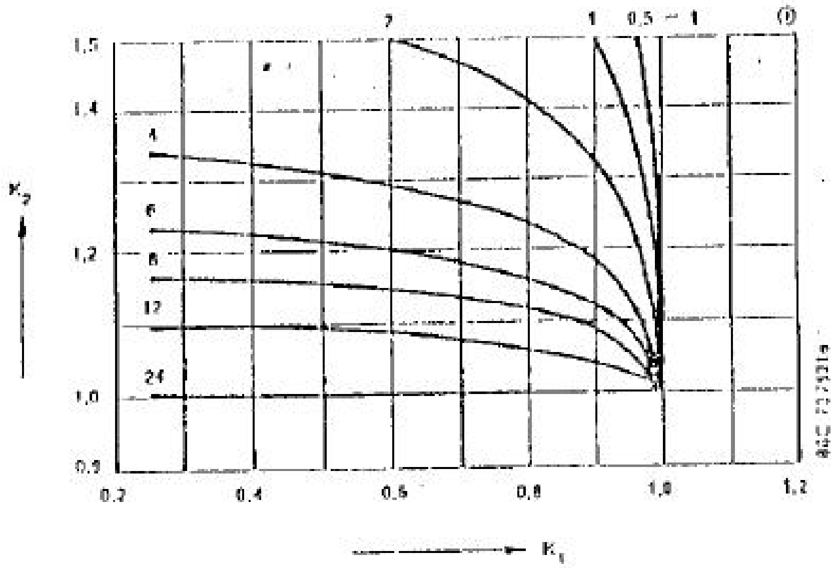
Dry and immersed transformers (except mineral oils) are considered fire proof, this does not mean these materials are non-inflammable although these materials have fire point (is the temperature at which occurs continuous burning of the material when subjects to flam at its surface). The most important 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 (2-10) shows fire point for some fire proof materials (carbonaceous materials are excluded for their danger on the environment). From the table it is clear that there is no great difference between the materials except insulation Class H, which can be considered practically fire proof. Poisonous effect of the vapors emitted from burning of these materials and the resulted danger must be taken into consideration in addition of the other features for comparison purpose.

Removal Heat Rate (RHR) resulted from the burned material is considered an important factor, where depend on it size and nature of the transformer enclosure. This rate consists of two components, one is convective and the other is radiative. The first component is higher in value and is considered a measure of destruction to the ceilings of the transformers buildings, while the second component shows the destructive effect of the fire on the walls and the equipments surrounding the transformer.

- Table (2-11) shows values of these components for some fire proof materials.

Assuming the same service life as for continuous operation at rated power and at an ambient air temperature of 20° C, the transformers may be subjected to a load cycle as shown by the curves below.



The curves are in accordance with the IEC recommendation of 1972 which permits a hot-spot temperature in the windings of 140° C.

in which:

K_1 = initial load referred to rating

K_2 = max. permissible load referred to rating

t = duration of K_2 in h

Note:

In certain cases the permissible overload obtained from the above curves may be limited by the tap changer and bushings. Therefore, if it is intended to operate the transformer with a load cycle involving overloads, the height of the latter and the nature of the load cycle should be stated.

Fig (2-25): Relation between K1 and K2 at different values of loading period t

Table (2-10): Fire point for some fire proof materials

Material*	Fire point (°C)
Silicone liquid	360
Midel 7131	310
Cast resin	350
Class H	†

*For comparison purposes mineral oil is 170°C. Askarel is non-flammable.

†These designs are virtually fire proof.

Table (2-11): Removal Heat Rate (RHR) values for some fire proof materials

Material	RHR	
	convective (kW/m)	radiative (kW/m²)
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 (2-26) shows these connections in addition to other connections.

  In this figure, HV vector diagram is taken as the original vector and the similar phase in the LV windings is related to it according to clock hour figure.
- Phase shift test for primary windings (High Voltage) and the secondary windings (Low Voltage) is neglected in case of use only one transformer for area network. If the network contains more than one transformer, all transformers must have the same phase relation, otherwise the transformers can not be operated in parallel or to covert the supply of the network from a transformer to another.

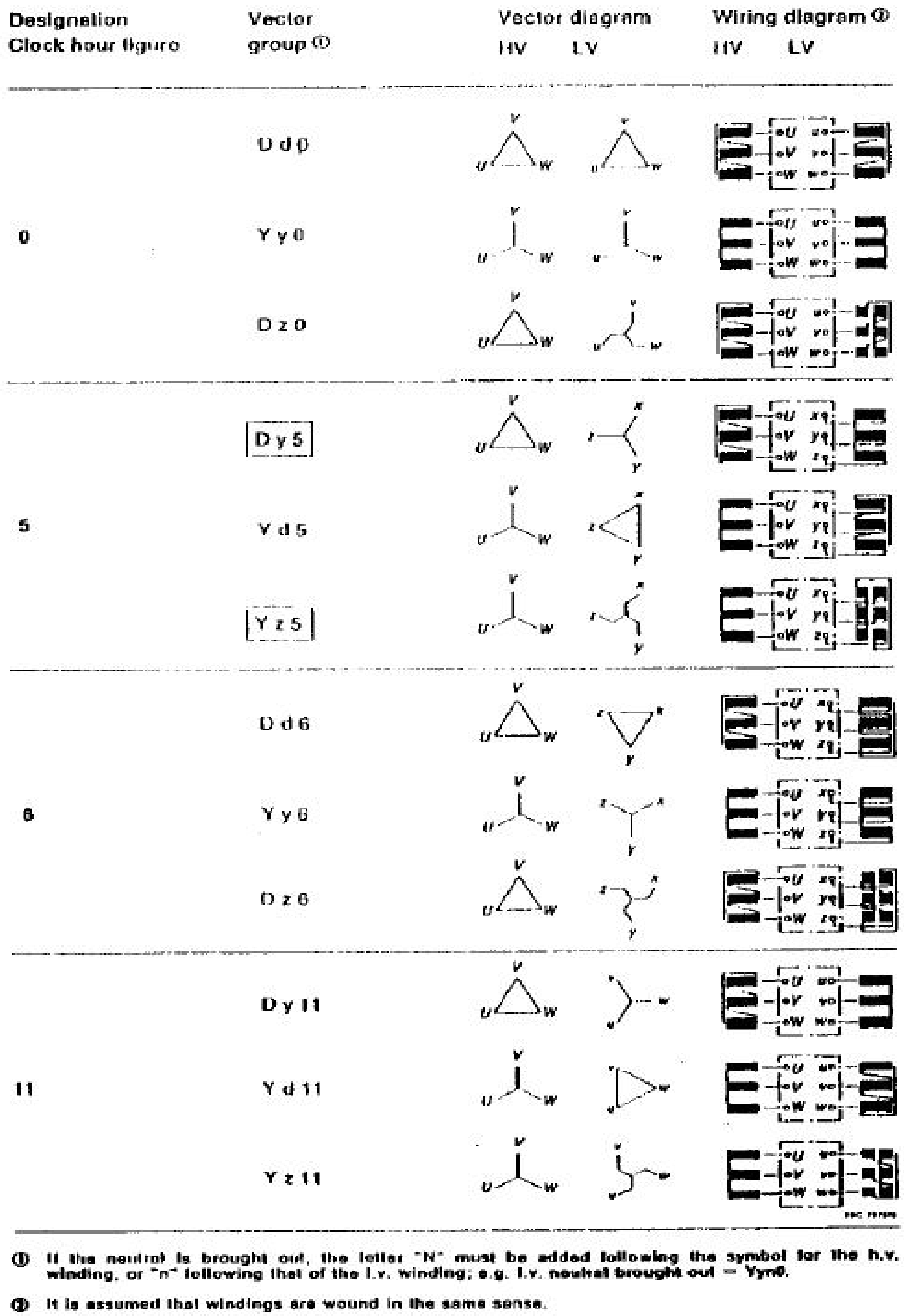


Fig (2-26): Commonly uses vector groups in distribution transformers

3-3-11 Terminals

- LV Terminals in the transformers are in the form of epoxy resin case contains set of pins connected to it cable terminals with screws.
- HV terminals are in the form of cables box filled with compound in case of paper insulated HV cables or upper cables box in case of XLPE or P.V.C cables provided with thermal shrinkable sleeves.

3-3-12 Transformers Cooling

Transformers are identified according to the used method of cooling. Table (2-12) shows the alphabetic letters used as symbols to indicate the cooling method.

- The simplest cooling methods are done by cooling the windings by natural air passing over the hot surfaces of the windings and transformer core, where heat is transferred to the air surrounding the transformer by convection of radiation. This method is described as Air Nature (A.N.).
- To overcome the obstacles that reduce heat transfer from the windings to air, forced-directed air is used over these windings to improve heat flow and increase cooling rates significantly. This method is known as Air Forced (A.F.).

Table (2-12): The alphabetic letters used as symbols to indicate the cooling method in distribution transformers

Kind of cooling medium	Symbol
Mineral oil or equivalent flammable synthetic insulating liquid	O
Non-flammable synthetic insulating liquid	L
Gas	G
Water	W
Air	A
Kind of circulation	
Natural	N
Forced (oil not directed)	F
Forced-directed oil	D

- These two methods can be combined in dry transformers by using natural air cooling with the operation of an automatic fan in case of temperature rise in transformers more than the normal limits. This method is called (AN/AF).
- In case of the transformers immersed in liquids, two groups of letters must be used to describe method of cooling, the first describes windings cooling and the second describes method of cooling surface of the liquid. In case of windings immersed in oil are cooled naturally and in the same time this oil is cooled naturally by air. The letters indicating this are ONAN. If the oil is cooled by the forced air, the cooling method is ONAF. The two methods can be combined through operation of an automatic fan to force the air over the surface of the liquid in case of temperature rise more than a certain limit. This method is known as ONAN/ONAF, so the power of the same transformer can be increased significantly.
- When using a pump to help in oil flow inside the transformer in addition to operation of a fan to force the air, the method is called OFAF.
- For transformers of power 50 KVA or more the natural method of cooling ONAN requires greater cooling surface for oil tank than the normal surface of this tank. This additional surface can be obtained whether by using pipes welded to the tank walls carrying the hot oil from upper most of the tank to the bottom of the tank as used in the past or to use cooling plates similar to that used for hot water, which are installed in the form of banks at the sides of the tank to increase the cooling efficiency and decrease the cost in case of using the pipes. Now, oil tanks made from deep tortuous thin plates (1.2 mm) are used to obtain the highest natural cooling efficiency for the cooling oil of the transformers.

3-3-13 Ventilation of transformer enclosure

- The transformers used inside closed enclosure, its temperature will be higher at the same load than that used in the open air. So, to increase service life of the transformers, this matter must be taken into consideration when design transformers enclosure to limit this temperature rise.
- A balance must be made between advantages of using ventilation fans for these enclosures to limit temperature rise and the advantages of natural ventilation that does not depend on efficiency of performance and maintenance of these fans and the dangers resulted from the sudden stop of the fans.
- Temperature rise in transformers enclosures depends on the following:

(A) Transformer total losses.

(B) Net area of ventilation openings (inlet and outlet).

(C) Active vertical distance between inlet and outlet openings.

- Ideal location of air inlet opening is lower and under the center line (C.L.) of transformer radiator and to install the transformer as near as possible from it.
- Air outlet opening is at high location and must not directly over the transformer, but is located on the wall apart from the inlet opening to enable pass of the cold air over the transformer while passing from inlet opening to outlet opening.

- Minimum distance of the outlet opening from the inlet opening in the ideal case is equal to one and half height of the transformer.
- Net area of the inlet opening or the outlet opening is calculated from the following empirical formula:

$$A = 0.06\ P \qquad (1)$$

Where:

P = Total loss emitted from the transformers (KW)

A = Area (m^2)

Also, the following formula can be used:

$$AL = 0.188.\ \frac{P}{\sqrt{H}}$$

Where:

AL = Cross section area of both ventilation openings (inlet-outlet) (m^2)

P = Total loss of the transformer (KW)

H = Distance between center of the transformer to the center of the outlet opening (m).

- Fulfilling the above conditions, air temperature of transformer enclosure must not exceed the ambient temperature more than 7-8°C.

Fig (2-27) shows nomogram for determination of areas of air inlet and outlet.

Fig (2-28) 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,

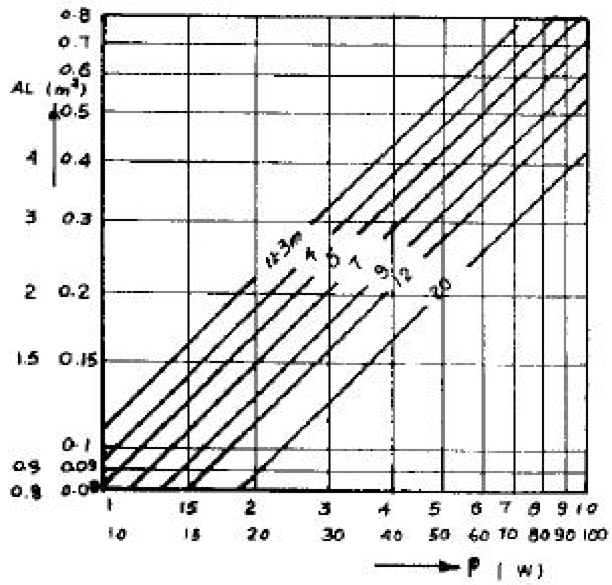
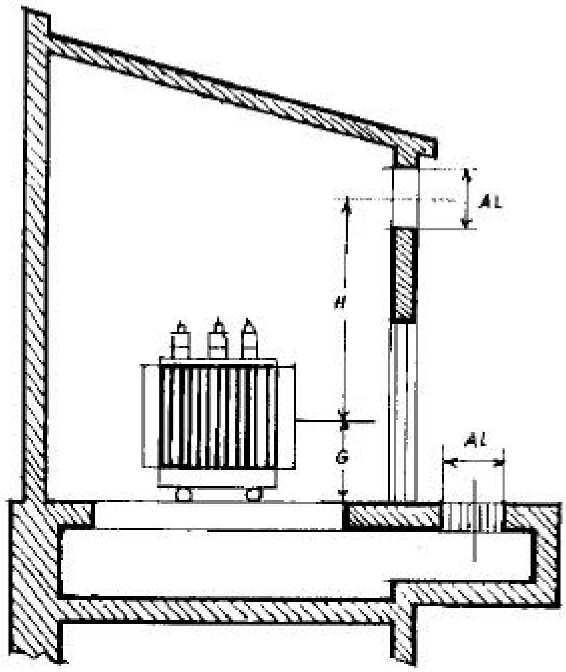


Fig (2-27): Nomogram for determination of areas of air inlet and outlet



Output KVA	63/ 100	160	250	400/ 500	630/ 800	1000/ 1750	1600/ 2000	2500
G mm	610	645	685	730	795	940	1075	1195

Fig (2-28): Installation of transformers in sealed enclosure 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.

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.

1. 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.
2. 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.

3. The temperature indicators are connected to alarm circuits or disconnection circuits. They can also be connected to three or four switches to operate fans or pumps to force the air or oil to a cooling cycle outside the transformers.

3-4 Electrical Cables

3-4-1 Current Rating

* When an electrical current passes in the conductor of the cable, heat is produced in the conductor and is proportional to the heat quantity produced per unit time and the product of the current passing in the conductor and the conductor resistance.

Therefore,

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

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

$$\theta = \frac{W}{t} \qquad (2)$$

Where:

θ = Heat flow per second

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

$$\theta = \frac{\Delta T}{Rth} \qquad (3)$$

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 (2-13) shows current ratings for copper cables laid in air with P.V.C insulated conductors.

* Table (2-14) shows current ratings for copper cables laid in the ground with P.V.C insulated conductors.

* Table (2-15) shows current ratings for copper cables laid in air with XPLE insulated conductors.

* Table (2-16) shows current ratings for copper cables laid in the ground with XPLE insulated conductors.

* Table (2-17) shows current ratings for multi-core cables with XPLE or PVC insulated conductors in an ambient temperature of 25°C.

3-4-2 Derating Factors

If cooling of the cable is restricted to a certain limit, the current flow in this cable must be reduced to prevent reaching to a high temperature exceeds the limits specified to the used insulation.

The factors that restrict normal cooling rate are:

Table (2-13) Current ratings for copper cables laid in air with P.V.C insulated conductors

Current rating and protection for cables laid in air with rubber, PVC or paper-insulated conductors, in accordance with NEN 1010 (2nd edition), Art. 152[1])

Nominal cross sectional area of copper conductor	Single-core cables[2])		Twin-core cables		Three- and four-core cables	
	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse
mm²	A	A	A	A	A	A
1.5	27	25	24	20	20	16
2.5	40	35	31	25	27	25
4	52	50	40	35	36	35
6	65	63	52	50	46	35
10	88	80	72	63	62	50
16	115	100	96	80	80	63
25	150	125	—	—	105	100
35	185	160	—	—	125	100
50	230	200	—	—	155	125
70	280	250	—	—	195	160
95	335	315	—	—	235	225
120	385	355	—	—	270	250
150	440	400	—	—	310	250
185	500	450	—	—	345	315
240	585	500	—	—	385	355
300	670	630	—	—	425	400
400	790	710	—	—	490	450
500	900	800	—	—	—	—
625	1040	1000	—	—	—	—
800	1200	—	—	—	—	—
1000	1360	—	—	—	—	—

Table (2-14) Current ratings for copper cables laid in the ground with P.V.C insulated conductors

Current ratings and protection for cables, laid in the ground with rubber, PVC or paper-insulated conductors, in accordance with NEN 1010 (2nd edition), Art. 153[1]).

Nominal cross sectional area of copper conductor	Single-core cables[2])		Twin-core cables		Three- and four-core cables	
	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse
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 (2-15) Current ratings for copper cables laid in air with XPLE insulated conductors

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

Nominal cross sectional area of copper conductor	Single core cables*		Twin core cables		Three- and four-core cables	
	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse	Current rating	Highest nominal value of the fuse
mm²	A	A	A	A	A	A
1.5	30	25	30	25	25	20
2.5	45	35	40	35	35	25
4	55	50	52	50	45	35
10	75	63	70	63	60	50
6	100	80	95	80	80	63
16	135	100	125	100	105	80
25	185	160	—	—	135	100
35	225	200	—	—	165	125
50	270	250	—	—	205	160
70	340	315	—	—	255	200
95	400					
		355	—	—	310	250
120	480	400	—	—	355	315
150	550	450	—	—	405	355
185	615	500	—	—	450	400
240	745	630	—	—	505	450
300	850	710	—	—	—	—
400	1000	800	—	—	—	—

Table (2-16) Current ratings for copper cables laid in the ground with XPLE insulated conductors.

Current ratings and protection for cables, laid in the ground with cross-linked polyethylene) insulated conductors[1]).

Nominal cross sectional area of copper conductor 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 (2-17) Current ratings for multi-core cables with XPLE or PVC insulated conductors in an ambient temperature of 25°C.

Number of cores	Current per core in A			
	Rubber or PVC-insulated cables		(XLPE)-insulated cables	
	1.5 mm²	2.5 mm²	1.5 mm²	2.5 mm²
6	15	21	18	25
7	14	19	17	24
8	13	18	16	23
10	12	16	14	20
12	11	15	13	19
14	10	14	12	18
16	10	13	12	17
19	9	12	11	16
24	8	11	10	14
30	7	10	9	13
37	7	9	8	11

4. Increase in ambient temperature.

5. Effect of the adjacent cables carrying current whether the cables laid on the walls, trays or in the ground.
6. Less of moisture in the ground in which the cables are laid.
7. Circumference of the cable installed totally of partially on a reel or cylinder.

In all cases, maximum current ratings in the tables must reduced by a certain percentage.

* Table (2-18) is used as a practical guide for derating factors for rise in ambient temperature, effect of grouping of cables, variation of thermal resistivity of the soil due to changing in moisture percentage and for cables on reels.

* In case of existence of more than one affecting factor at the same time, the derating factors must be taken into consideration corresponding to these effects. .

* Precaution must be taken in case of installing more than one cable in the same trench or duct, where it is difficult to provide sufficient ventilation and specifying accurate derating factor.

3-4-3 Voltage Drop

The voltage drop in the cable is the difference between the voltages measured at the two ends of the cable.

Drop percentage of the circuit voltage rating is:

- Maximum 5% for lighting system
- Maximum 2% for power system.

Table (2-18) Practical guide for derating factors for rise in ambient temperature, effect of grouping of cables, variation of thermal resistivity of the soil due to changing in moisture percentage and for cables on reels

Derating factors for the variation in ambient temperature exceeding 25 °C.

temperature			25 °C	30 °C	35 °C	40 °C	45 °C	50 °C	60 °C	70 °C
derating factor	XLPE	f1	1.00	0.95	0.91	0.87	0.82	0.76	0.65	0.50
derating factor	PVC	f2	1.00	0.93	0.85	0.76	0.65	0.53		

Derating factors for grouping of cables laid in air

number of cables			2	3	4	5	6
clearance equal to cable diameter	XLPE and PVC	f3	0.94	0.90	0.87	0.85	0.83
cables laid side by side without interspace	XLPE and PVC	f4	0.81	0.79	0.77	0.75	0.73

Derating factors for grouping of cables laid direct in the ground (depth appr. 70 cm, distance between the cables appr. 10 cm)

number of cores and cross sectional area of the conductor				number of cables							
single core	three and four cores			2	3	4	5	6	7	8	9
95 mm² and less	35 mm² and less	f5	XLPE and PVC	0.90	0.82	0.78	0.74	0.72	0.70	0.68	0.66
120/300 mm² incl.	50 and 70 mm²	f6		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		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	0.56	0.38	0.32	0.27	0.24

* Accurate voltage drop can be calculated from the circuit vector diagram, and in most cases the accurate calculation is not necessary and it is sufficient approximate calculation as follows:

A) For DC

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

Where:

$\Delta\upsilon$ Voltage drop between the two ends of the cable in volt (measured between the poles)

I = Current rating in Ampere.

l = Cable length in meter.

r = Cable resistance in ohm/km

B) For single phase AC

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

$\Delta\upsilon$ Voltage drop between the two ends of the cable in volt (measured between the phase and the neutral point)

I = Current rating in Ampere.

l = Cable length in meter.

r = Cable resistance in ohm/km

Cosφ = Power factor of the cable load.

C) For three phase AC

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

Where:

$\Delta\upsilon$ Voltage drop between the two ends of the cable in volt (measured between the conductors of the same phase)

I = Current rating in Ampere.

l = Cable length in meter.

r = Cable resistance in ohm/km

$Cos\varphi$ = Power factor of the cable load.

Note:

The above values are sufficiently accurate when the impedance of the cable (χ) can be neglected compared with cable resistance (r), which is the normal case of cables with cross section area not more than 70 mm^2.

For cables with greater cross section area, the voltage drop is calculated as follows:

(1) For single phase AC

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

(2) For three phase AC

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

Where:

χ is cable impedance in ohm/km

Can be taken 0.1 ohm/km

* The nomograms shown in Fig (2-29) and Fig (2-30) are used for practical applications.

3-4-4 Cables short circuit

3-4-4-1 Thermal short circuit rating with PVC insulted

Thermal short circuit rating is calculated from the following formula:

$$Ik = \frac{109}{\sqrt{t}} .q$$

Where:

IK = Short circuit rating in KA

t = Short circuit time in second

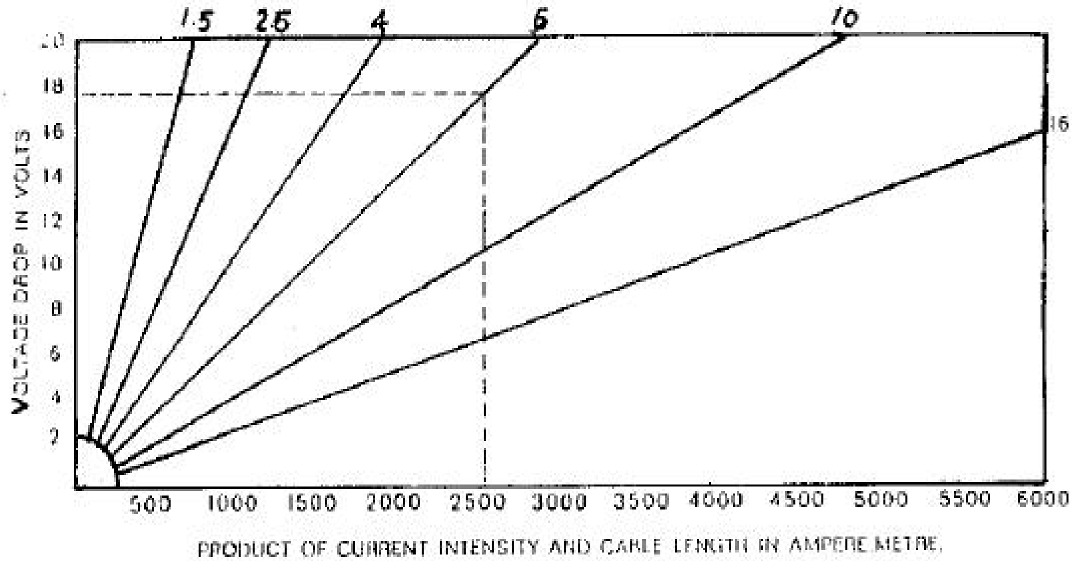


Fig (2-29): Nomogram for calculation of voltage drop for double cores cable, single phase alternating current, Cosφ = 1.0

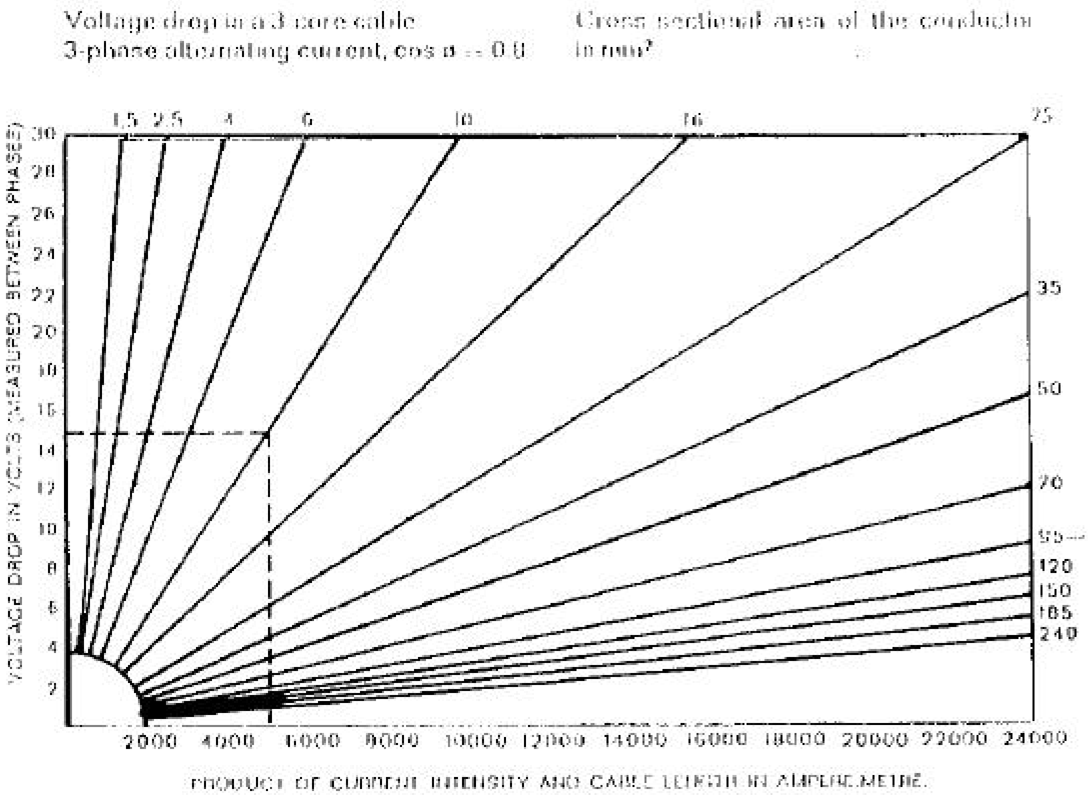


Fig (2-30): Nomogram for calculation of voltage drop for 3- core cable, 3- phase alternating current, Cosφ = 0.8

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

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

Fig (2-31) 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 (2-32) 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.

3-4-5 Design considerations for installation of cables, pipes and their dusts

Egyptian Code Concerning Design Criteria and Rules of Electrical Installation in Buildings must be taken into consideration when determine specifications of cables, fittings, pipes and their ducts.

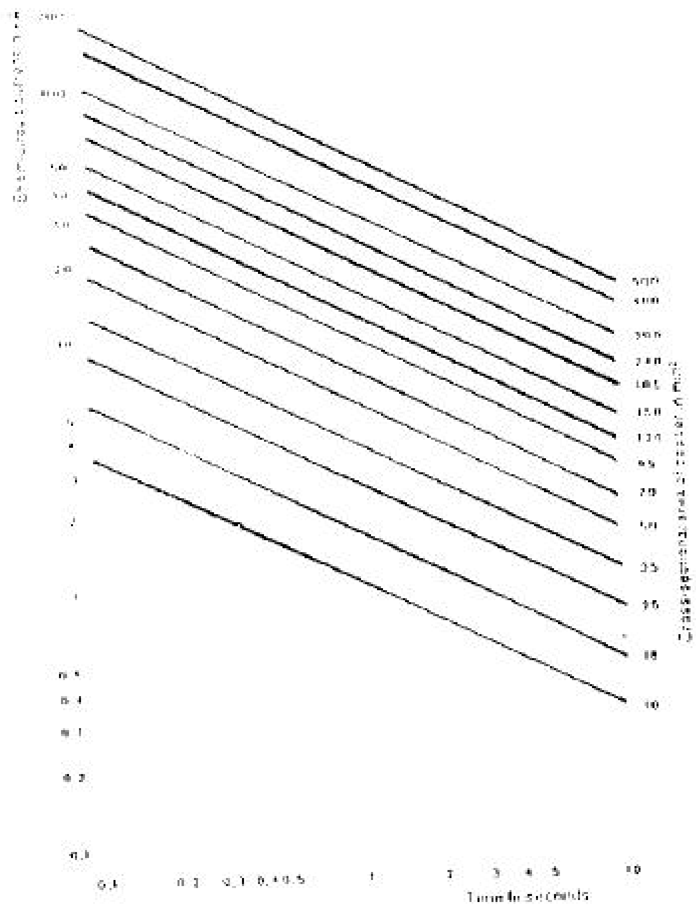


Fig (2-31) Nomogram the relation between the short circuit, time and the cross section area of the cables with PVC insulted conductors (LV copper conductor cables)

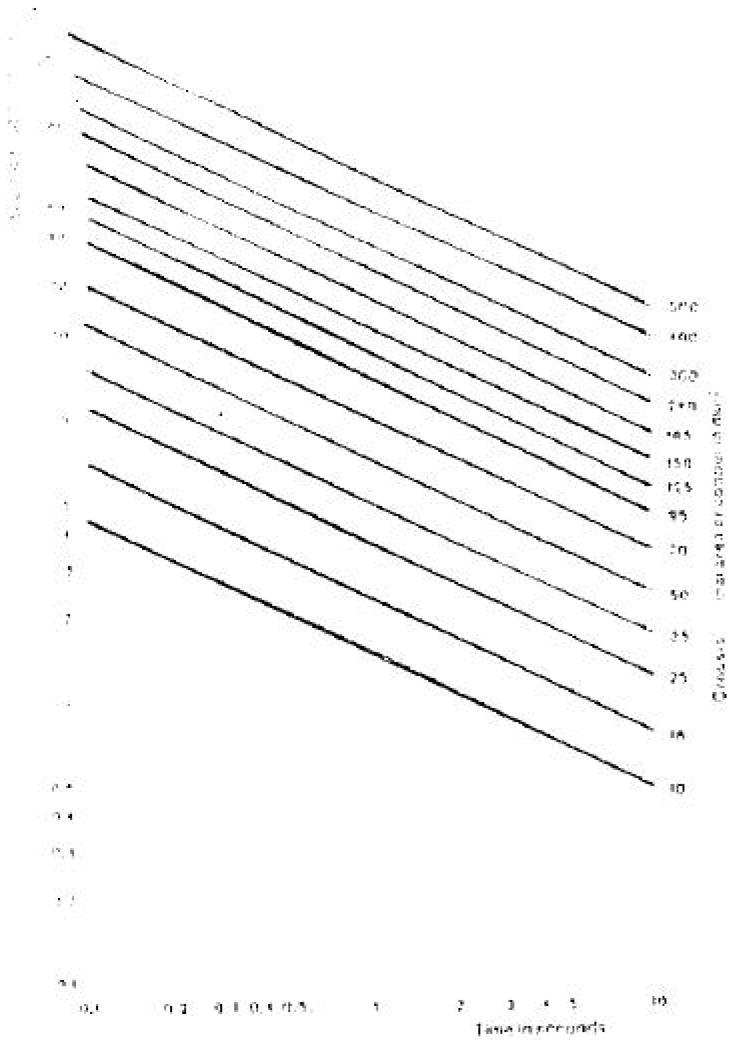


Fig (2-32) Nomogram the relation between the short circuit, time and the cross section area of the cables with XLPE insulted conductors (LV copper conductor cables)

3-5 Electrical Power Generation Station

3-5-1 Introduction

For the importance and necessity of continuous lift of the pumping station in case of current interruption from the city supply to the station, it must provide alternative power supply to the plant by construction of emergency electricity generation station as integral part of the plant for continuous operation purpose.

3-5-2 Power of the emergency power station

Emergency power station must have a power commensurate with the operation of all pumps and operating devices in the pumping station.

3-5-3 Number of units of emergency power station

According to the above mentioned emergency power for operation of the pumping station, minimum number of the generation units shall be determined to achieve balance between economic aspects and secure of operation taking into consideration the available area.

3-5-4 Specifications of Generation Unit Motors

Power : Emergency power / number of generation units.

Cycle : Four strokes

Fuel : Diesel/ solar with sprincklers, fuel pump and turbo charger.

Cooling : Water or air according to the location of the station and the availability of the cooling water.

Starter	: Electrical or compressed air
Cylinders order	: According to the power and the available area, row of V type will be selected.
Engine Speed N	: Engine speed in specified in rpm according to current frequency (f) (50 c/s) and number of poles of the electrical generator (P) by the following equation.

$$f = \frac{P.N}{60} \quad Hz$$

Motor speed is taken as follows:

Less than 300 KW	: 1500 rpm
More than 300 KW up to 600 KW	: 1000 rpm
More than 600 KW up to 1500 KW	: 750 rpm
More than 1500 KW	: 600 rpm

3-5-5 Diesel Motor Components

Motor Intake

- Air requirements are estimated by 0.07 m^3/min/hour brake of the motor power.
- Air intake is provided by internal air filter.
- When using turbo charger, it must provide a straight length not less than 5 cm before connection it with the motor air intake.

- Air pipe connections must be designed in a way that facilitates replacement of the filter in addition to isolation of motor vibrations and noise.

Engine Exhaust

- Exhaust pipes and the silencer must be thermally insulated to protect the workers in generation house and prevent temperature rise in the house that may affect intake air temperature or starter batteries.
- Path of the exhaust pipes must be kept away from any flammable materials by a distance not less than 25 cm.
- Exhaust pipes must pass inside enclosure of diameter not less than one and half exhaust pipes diameter when passing through the walls or the ceilings.
- End of the exhaust pipes must be chamfered at angle from 30° to 45° to reduce formation of gas cyclones, reduce noise and protection from rains.

House Ventilation

- Generation units' house must be ventilated, as the good ventilation saves from 6% to 10% of fuel consumption due to the heat dissipation in the house, improves production of generation units and distribution boards and provide suitable atmosphere for operation and maintenance works in the house.
- Ventilation of the house must be kept at 38°C.

Engine Cooling

- Cooling cycle must contain thermostat allows operation over 80°C to keep the motor efficiency at starting up.
- Temperature difference between inlet and outlet cooling water must be between 5°C t0 8°C.
- Cooling water pressure must be between 0.25 to 0.45 kg/cm^2 to prevent formation of vapor inside the radiator and engine cooling chest.
- Temperature of the upper part of the radiator must be less than 100°C to prevent confinement of cooling water pump and increase its efficiency.
- Speed of pure cooling water is between 0.6 m/sec and 2.5 m/sec, while it is from 0.6 m/sec and 1.9 m/sec in case of raw water.
- Quality of cooling water (pure or raw) must be taken into consideration when determining the velocities inside cooling cycle pipes.

3-5-6 Fuel System

Main Storage

- Fuel is stored in large tanks with sufficient volume for operation of all generators at full load for a period ranging from one week to two weeks continuously according to the distance from supply sources.
- Main fuel tanks may be under or over ground surface.
- Fuel tank is made from treated steel plates and not from galvanized iron to avoid chemical reactions with the fuel.

- Main tanks must be over ground surface in case of availability of the necessary area away from the surface motion and under the ground surface in case of unavailability of the necessary area.

Tank Components

- Tank filling pipe installed in a way that achieves safe operation processes.
- Tank vent pipes.
- Measuring hole.
- Drain valve at the bottom of the tank to suck the sediments at regular intervals.
- Electrical pumps to transfer fuel from main tanks to daily tanks.
- Tank components are made from treated steel (and not galvanized iron), steel or copper.

Daily Storage

- Daily tank is installed in generators house.
- Fuel suction and return pipe diameters must not less than motor components and pipes diameters for the all pipe lengths.
- Pipe diameters are increased in case of supply fuel to more than one motor, and also in case of temperature decrease.

Filters

- Filters are installed to prevent fuel sediments which cause blockage of the fuel injection sprinkle nozzles and injection pumps.
- Filters are provided with grid screens with spacing 0.3 mm.
- Large motors are provided with two filters with a means of change of any of them to facilitate cleaning and replacement of the damaged filter during operation to avoid fault of the motor.

3-5-7 Starting Systems

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

- Electrically (battery + starter motor) for the engines of power up to 500 KW
- Compressed air for the engines more than 500 KW.

Electrical Starting motion

The following points must be followed when using this method:

- It is preferred to use lead acid batteries because they are less expensive than the nickel cadmium batteries.
- Generators house temperature must not exceed 38°C to maintain the power and operation efficiency of the batteries.
- Copper cables must be used in the connections between the batteries and starter motor.
- Battery charger must be used in generators house to charge the batteries during stop operation of the generators, in addition to the DC generator which charges the batteries during operation of the engines.

Starting motion by compressed air

The following must be taken into consideration when using this method:

- Provision of air compression ranging from 7 kg/cm^2 to 16 kg/cm^2 from the an air compressor, air tanks and non-return valves between them.

- Volume of the air tanks must be selected according to air quantity necessary for each operation, number of operations, tank pressure and atmospheric pressure. This volume is determined by supplier of the engines.
- The main air compressor is operated by internal combustion engine turned by benzene, kerosene or solar.
- Provision of an emergency air compressor operated by electrical motor.

4- Design rules for construction and architectural works

4- Design rules for construction and architectural works

First: Architectural Works

4-1 Layout

Units must be distributed on the site layout of the pumping stations in a way that allows the provision of the following rules:

- Main roads and sub-roads must be with the width that allows entrance and exit of the cars and to perform the necessary maneuvering, taking into consideration levels of the roads and sidewalks with the constructions that will be implemented.
- Existence of the guard rooms and information room adjacent to the main entrance of the plant.
- Provision of green areas between the units.
- Plant units must be coordinated in a way that allows easy motion inside the plant between the different units.
- Administrative building units must be away from treatment units and to study wind direction to avoid subjection of the buildings to bad smells and gases.
- The site must be provided with water, irrigation, fire, sanitary drainage, and electricity and lighting networks.
- Construction of suitable fence.

4-2 Project Units

The following are the design rules for some units that consider the aesthetical aspects (color and heights coordination of project units):

4-2-1 Pump House

- Easy electricity supply taking into consideration the economic aspects.
- The distance between crane beam and the lowest point of ceiling beam must not less than 1.5 m.
- Provision of sufficient ventilation and lighting inside the house.
- Provision of handrails around sump roof openings inside motors house.
- Cable trenches must be submersed in the floors.
- Pump house floor must be from ceramics resistant to acid and friction and the walls from faience at suitable height.

4-2-2 Generator and Transformers Building

- Specifications and dimensions of the building must be in conformity with Ministry of Electricity conditions.
- Easy access to transformers building doors at the external fence and at the main roads and sub-roads.
- The distance between crane beam and the lowest point of ceiling beam must not less than 1.5 m
- Provision of sufficient ventilation and lighting inside the house
- Internal finishing must be from materials suitable to the building. Floors must be from ceramics resistant to acids and friction and cable trench covers at the ground level to not hinder the motion.

4-2-3 Workshops and Stores

- The distance between crane beam and the lowest point of ceiling beam must not less than 1.5 m
- Provision of sufficient ventilation and lighting inside the house
- Easy access of cars, equipments and instruments to workshops and stores entrance.
- Near from workers rest room and toilettes.
- Internal finishing must be from materials suitable to the building. Floors must be from ceramics resistant to acids and friction and cable trench covers at the ground level to not hinder the motion

4-2-4 Administration and lab building

- Must be near from the main entrance for easy control of workers and access to different buildings.
- Study wind direction to avoid subjection of the buildings to bad smells and gases with the provision the lab with a tower to drain the gases.
- Provision of sufficient ventilation and lighting inside the unit.
- Floors must be from ceramics resistant to acids and walls from faience
- Provision of upper side holes for installing suction gas fans such that level of thee holes is less than level of lab ceiling by a distance does not exceed 50 cm.

- Provision of sanitation installations for the basins (water- sanitary drainage)
- Bases must be covered with ceramics resistant to acids.

4-2-5 Chlorine Building

4-2-5-1 Chlorine store

- The store must be at the south part of the plant away from workers, administrative buildings and residential complexes.
- The store must be away from fuel stores, workshops and any source of flammable materials.
- The store must be adjacent to cylinders building, containers, evaporators and chlorine injection devices.
- The store must has a sufficient area to accommodate the number of the cylinders or the containers that are put in horizontal position in two or four parallel rows such that the distance between the axes of the cylinders of the containers is 1.10 m and allow operation of the plant for a period not less than 10 days.
- The store must be in a good ventilated location and insulated against direct sunrays on the cylinders or containers such that the temperature inside the store does not exceed 45 °C
- Easy access of cars carrying equipments, chlorine cylinders and maintenance tools.
- Anti- chemicals finishing materials must be used by laying ceramics on the floor resistant to acids and the walls from faience with suitable height not less than lower threshold of the windows.

- Cylinders iron bases must be provided with four iron rollers for each cylinder such that the bases are at 1 m distance form the side walls to facilitate motion and adjust position of the cylinders and the valves on correct operation position.
- It is recommended to provide the building with upper cranes (monorail) at a distance not less than 1.5 m between the crane beam and the lowest point on the building beam for each row of cylinders such that it is not intersecting with the falling beams at the entrance of chlorine store with the path of crane beam. This beam must be extended out the building by 1.5 m for handling (loading and discharging) the cylinders from and to the transporting cars, taking into consideration that crane beam axis is the same as the axis of the cylinder bases axis.
- The store must be provided with leakage detector and alarm devices.
- Concrete ducts with covers must be constructed for easy removal and path of chlorine injection pipes made from PVC of similar.
- Must provide ducts for drainage of washing water.
- The store must be provided with neutralization stank and insulation room to it the defective cylinder or container will be transferred to be isolated from the plant. The following conditions must be provided for base of the neutralization tower base:

• Must be of height not less than 2 m from building floor.
• The hold used for tower installation must be covered air seal material.

- The store must be provided with ventilation holes provided with mechanical ventilation devices (air suction fans) of height not more than 50 cm from building floor. The hole must not less than 35 × 35 cm and the distance between each two holes is nor more than 2.0 m.

- The store is provided with additional ventilation devices that change store air operate in emergency case, and the air is discharged in isolated ducts to neutralization room or tank for reaction of the polluted air with the chlorine by set of acoustic soda sprinklers.

4-2-5-2 Devices room

- Must be adjacent to cylinders or containers store.
- Provision of sufficient ventilation and lighting inside the unit and must have one door for entrance of individuals.
- Must be provided with mechanical ventilation system similar for ventilation system of the closed store.
- Room ceiling height is not less than 3.5 m
- Sufficient area to accommodate the evaporators (if necessary) and adding devices taking into consideration the following:

* Distance between the evaporators not less than 1 m
* Distance between the face of the evaporators and the rear wall not less than 1.75 m
* Distance between chlorine injection devices not less than 1 m
* Distance between the back chlorine addition device and the wall not less than 1,75 m

Any length of the room is not less than 5 m and the width depends on the number of evaporators and chlorine injection devices.

Second: Construction Works

Refer to Egyptian Codes concerning construction works.

5- Preparation of Tender Documents

5- Preparation of Tender Documents

5-1 Introduction

Released tender documents must contain technical information of the project, general and special conditions, which are the provisions referred to them contract parties, if necessary.

5-2 Contents of tender documents

Tender documents contain the following volumes:

- General and special conditions and technical specifications.
- Estimated bill of quantities
- As built drawings.
- Any other documents prepared by the designer, such as borings report, analyses of soil and groundwater.

5-2-1 Volume (1): General and special conditions and technical specifications of the project

This volume shall contain:

(A) Invitation to tender.

(B) Tender form.

(C) Instructions to bidders.

(A) Invitation to Tender

Invitation to tender will be in one or two pages with brief description about the project and tender procedures. It also contains method of obtain copy of tender documents, price, date and place of submitting these documents. The tender is published in the daily newspapers (two widely spread newspapers) in two consecutive days.

(B) Tender Form

Tender form determines standard format for the contractors to submit their prices and offers to the employer which facilitates technical and price comparison works for equal opportunities.

(C) Instructions to Bidders

Instructions to bidders are the standard base of the bids that help to arrange bid contents in standard order according to tender form. These instructions shall cover the Following:

- Definitions.
- Offer of bidders.
- Tender documents.
- Tender procedures.
- Tender requirements.

- Mail instructions.
- Primary and final insurance
- Contract form between the owner and the contractor.
- Additional instructions.

5-3 Insurance Forms

Tender documents contain format for primary insurance submitted with the bid and the final insurance that shall be submitted by the winner contractor from approved bank. The format shall contain a provision states that the employer has the right to issue this insurance for his benefit at first statement from the bank in this regard without any objection from the contractor. This insurance must be valid to cover its purpose.

5-4 Contract between the owner and the contractor

This contract is considered an independent document and shall cover five main principals as follows:

- Legal capacity and competence of the parties to act and conclude the contract. Sufficient number of copies must be signed for the owner, contractor, the engineer (if any), contract and purchasing department and state counsel.
- Clear brief description of the project.

- Expected implementation period. This part is very important, as according to it fine delays or contract extension, etc. may be imposed.
- The price, whether a fixed price covers the entire project, price for each item of works or LS price for each group of similar items of the works, as agreed upon.
- Terms of payment through periodic payments according to work progress and what agreed upon such as deduction of certain percentage accumulated until the preliminary handover, the deduction from the advance payment paid to the contractor, etc.

In addition to the closing payment of the project, this is considered from the most important legal payment during the project.

This contract contains also to what extend the relation between this document and other tender documents in terms of legal capacity, as this document is the only one signed by contract parties.

5-5 Contract Conditions

Conditions of the contract are divided into two parts: general conditions and special conditions (completing conditions).

5-5-1 General Conditions

General conditions cover rights and obligations of both the owner and the contractor and determine scope of work and responsibilities of the consultant who supervises the implementation (if any), works and responsibilities of project manager.

Contents of general conditions are:

A- Definitions

Important items are defined accurately and clearly, such as:

The owner - The consultant engineer- project manager -The contractor - The Subcontractor -The works- The Project- Tender documents- drawings- Completion date of the project- Project commence Date.

B- Rights and Responsibilities

Rights and responsibilities of each party are explained in detail to know each party his rights and responsibilities under the contract as well as the relations with the sub contractors, where rights and responsibilities of the contractor extend to them.

C- Using others

In general, the owner has the right to perform some works of the project by himself or by independent contractor.

Therefore, the problems resulted from overlapping or efforts cooperation that affect works of other must be added and detailed in the general conditions.

D- Settlement of Disputes

Conditions shall be laid in detail to determine method of settlement of disputes resulted from the work whether amicably or by arbitration.

E- Duration of the project

Project start up date and completion date is determined and accordingly the period necessary for execution of the project. On the basis of this, the contractor shall make the time schedules necessary for completion of the project to be approved from the owner or his representative. According to these schedules shall specify any delay in works, its reasons and to what extend the contract needs to amend the time schedule according to the delay or to impose delay fines, as the case requires. The force Majeure must be specified for the circumstances out of control of the management during which the work is stopped. It must also specify working hours, official holidays and occasions for the contractor to be aware in this regard.

F- Payments

Payments will be prepared according to work progress in a defined and clear way, date of submitting these periodic payments and its least value, period necessary for their revision by the owner or his representative in technical and financial affairs and return procedures of these payments in case of mistakes in different stages of revision.

Also must state that approval of the owner for issuance of these dues does not consider approval of acceptance the work.

Also must state that the contractual and legal reasons that allow to the owner to seize and hold issuance of contractor dues against failure to repair the defected works, claims filed from the third party and failure of the contractor to comply with conditions and provisions of the contract.

G- Procedures of preliminary and final handover

1- 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 is defective or damaged during guarantee year, the contractor shall replace the defective or the damaged part or perform repair if there is benefit from the repair. If the contractor fails to perform the repair, the repair will be performed by deducting the cost from his dues or according to the provisions of the contract in this regard. Warrantee of the replaced part extends to one year from date of replacement.

2- Final Handover

- Before the end of warrantee period and the contractor has completed all of his obligations, the contractor shall notify the owner in writing to specify date for inspection and form final handover committee to include the owner and the body benefited from the project which was trained on operation and maintenance during the warrantee year.
- 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.

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.

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.

D- Technical Specifications

Technical specifications are completing the shop drawings, where they express the requirements in words and shows quality of the materials, supplies, equipments and technical construction methods.

Technical specifications are considered the greatest part of the contract according to the following categories:

General requirements, site works, concrete works, masonry works, metal works, wood works, insulation and protection, doors, windows, finishing, special works, equipments, furniture, special construction, conveying systems, mechanical works and electrical works.

These works are divided into four sections:

- General, materials, execution and method of calculation.

"**General**" section contains definition of the scope of work in this section, including quality control, information about the supplies and equipments, handling and storage requirements and warrantees.

"**Materials**" section contains brief description of the materials used in this section as a guide for the producers. "**Execution**" section contains details of methods of construction, performance of works, inspection, acceptance and tests. "**Calculation**" section verifies if this party of the works are loaded on contract items, item price, LS, etc.

E- Estimated Bill of Quantities

- Estimated bill of quantities contain work items, brief description of each item, method of calculation, whether with unit of area, volume or LS, and the estimated quantity of each item.
- The contractor shall price each item.
- In bill of quantities, if the contractor did not price an item, the price of this item is loaded on the prices of the other items of the contract upon execution, however specifying the highest price for this item in the other offers when evaluating this offer by evaluation committee.
- The quantities listed in the bill of quantities are estimated and the owner is entitled to increase or decrease these quantities by 25% with the same contract prices, and the quantities that exceed this percentage, their new prices shall be agreed upon.

Chapter 3: Implementation Conditions

1. Project implementation management
2. Site planning and preparation
3. Civil and architectural works
4. Mechanical and Electrical Works
5. Tests
6. Performance Tests and Handing Over

1- Project Implementation Management

Success of any project is measured by its completion on time according to contract documents, technical conditions, specifications and shop drawings.

The access key to project success is the provision of continuous communication and explanation means between the parties working in the project through a relation between project owner, consultant and contractor that helps execution of the works according to the time schedules specified for completion of this project.

Volume of labor required to complete the project depends on volume and condition of each project. Fig (3-1) illustrates organizational structure of project management.

For good coordination between the three parties, the following system shall be followed:

A Project owner shall contract with the contractor entrusted to execute the contract according to the applicable rules and laws.

B Project owner shall form execution unit for technical revision of all execution steps and know the obstacles and problems and provide their technical, financial, administrative and legal solution.

C The execution unit shall coordinate with the project consultant who performed studies and design works and preparation of contract documents for supervision of execution.

D Chairman will be appointed for the execution unit (project manager) to coordinate between the staff inside the unit and put work rules for the relation between the execution unit and the consultant.

E Project consultant shall coordinate between owner, contractor and consultant works. Fig (3-2) shows project execution unit and specifies its responsibilities as follows:

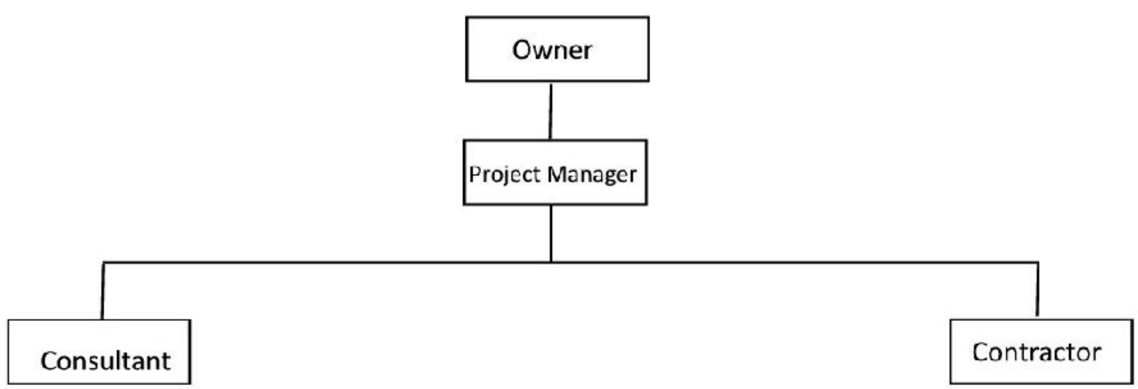


Fig (3-1): Organizational Structure of Project Management

Execution Unit

Project Manager

Financial and Administrative Affairs

Technical Affairs

Fig (3-2): Project Execution Unit

1-1 Project Manager

A Competent and can act to manage the project.

B Responsible about supervision of execution all works and activities and has the authority to control, familiarize and coordinate between different technical, financial, administrative and legal activities.

C Select the ideal method to execute the works and take into consideration the economic aspects, time and effort to achieve the objective towards completion of the project on a timely manner and take the measures needed to correct the course of implementation to complete the project successfully on time within the limits of the available funding.

D Project manager shall select the technical manager and financial and administrative affairs manager and authorize them to form and approve the assisting staff for both of them.

E Approve issuance of consultant dues under the contract.

1-2 Technical Affairs

1-2-1 Design Engineers

Revision works of the drawings submitted from the consultant office shall be conducted by specialized engineers for conformity of the hydraulic, architectural, civil, mechanical and electrical drawings and ensure availability of sufficient number of shop drawing copies.

1-2-2 Execution Engineers

A Execution works will be conducted by specialized engineers in different specializations to follow up execution stages.

B Prepare periodic reports about work progress, revise and sign daily follow up records by the consultant and the contractor and list any technical remarks or problems that may hinder progress of execution.

C Revise and compare the periodic payments according to the actually executed quantities with the shop drawings and the records submitted from the contractor and approved from the consultant.

1-3 Administrative Affairs

1-3-1 Financial and Administrative Manager

A Specialized accountant shall be appointed to perform this work in terms of financial and administrative aspects of the project and shall provide assistance and advice to the project in his scope of work.

B Shall follow up project financial and administrative works; submit periodic reports to the project manager and proposals on how to solve the financial and administrative problems that object progress of work.

C Shall select financial and stores audit staff.

1-3-2 Financial Audit

Specialized accountants shall be appointed to perform the following works:

A Review the payments from an accounting point of view and conformity of the rates with the contracts.

B Follow-up the financial position of the project up to date and maintain records that indicate the amounts available, what has been disbursed and the remaining.

C Compare expenditure with the execution timetable.

1-3-3 Stores Accounting

Specialized accountants shall be appointed to perform the following works:

A Maintain regular records show all the supplies, their dates of supply and value.

B Review the supplied equipments according to the contract on the packing lists.

C Maintain regular records about the adjustments of each documentary credit.

1-4 The Consultant

Responsibilities of the consultant are determined in the following:

A Prepare typical report forms, methods and procedures of work progress.

B Prepare rules to control how to sound managing of the project within its actual budget.

C Select high efficient technical supervision team in different specializations.

Fig (3-3) shows organizational structure of the consultant.

1-4-1 Technical Supervision

A Follow up the daily works being carried out by the contractor and take the necessary samples for test.

B Follow up the execution situation and its conformity with the approved execution schedule.

C Review and approve works counting books submitted from the contractor

D Review the submitted payments from the contractor and approve them for issuance.

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.

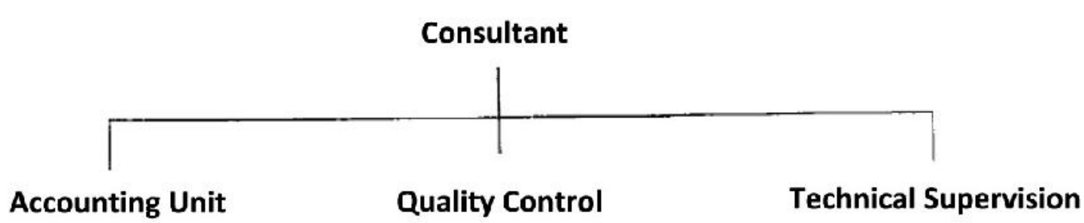


Fig (3-3): Consultant Organizational Structure

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 (3-4) shows organizational structure of the contractor.

1-6 Resident Engineer

He is responsible about the following:

A Management of the project.

B Coordinate between his assisting staffs and specify their duties.

C Revise the executed works through time schedules, revise and approve the payments prepared by executing engineer.

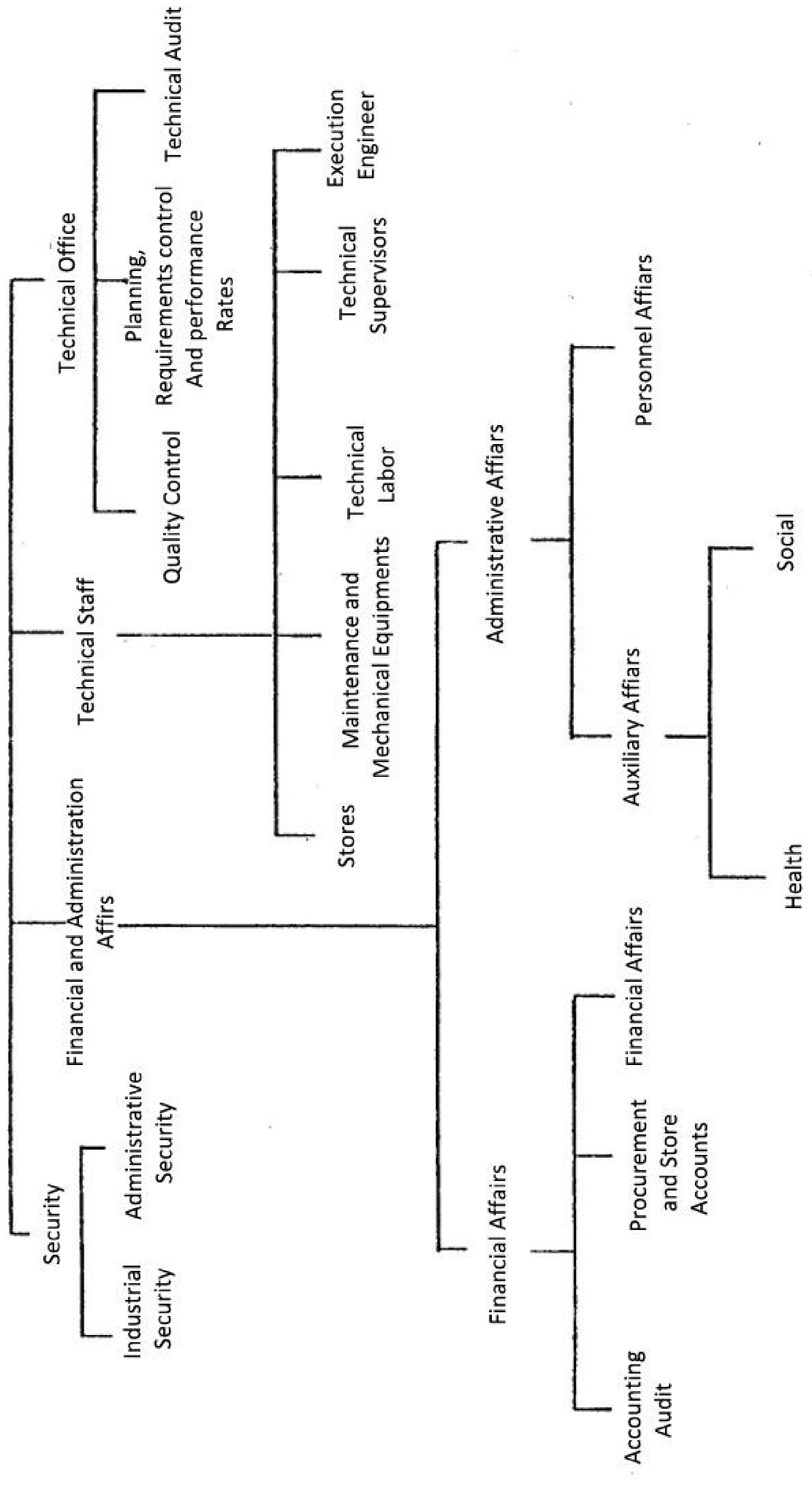
D Revise the financial situation and stores stock.

E Approve workers allowance on the light of the achieved works.

1-6-1 Technical Office

The technical office has the main role in preparation of all technical, design, planning, follow up, requirements and performance rates data for execution and full completion of the project according to the approved schedule. Role of the technical office is summarized in the following:

Fit (3-4): Contractor Organizational Structure



1-6-1-1 Technical audit: It is responsible about the following:

A Revise conditions, specifications and provisions dossiers.

B Prepare and count all work items required to be executed in the project.

C Revise bid documents, prepare and release tenders to subcontractors.

D Prepare and revise the payments according to the actually executed quantities and compare them with the shop drawings and collection records before submission to project consultant.

E Follow up execution of the project according to the time schedules.

F Prepare closing payments and preliminary handover reports of the project.

G Revise hydraulic drawings with the mechanical and electrical drawings and their conformity with the architectural and construction drawings with provision of copies of the shop drawings.

H Revise soil research report and ensure that locations of the executed borings are in conformity with what shown in the drawings and shall perform soil researches, if required, at his expensive.

I Prepare copies of as built drawings according to what actually executed for approval from the consultant.

1-6-1-2 Planning, control, requirements and performance rates

It is responsible about the following:

1. Prepare the planning budget and identify the obstacles and problems, if any, to be solved in timely manner.

2. Prepare different time schedules, use systems, such as personal computer, to facilitate revising all the information required to execute different stages of the project, provide the necessary requirements as well as communication and continuous cooperation between the concerned parties to complete the project on time.
3. Determine the resources necessary for the project, provide the materials and equipments according to the specifications with the necessary quantities on suitable times to execute the project in accordance with the specified time schedule.
4. Follow up execution of the project, action plan and all execution steps through the time schedules and performance rates and amend their course in case of any delay in execution of the project.
5. Follow up collection of financial claims.

1-6-1-3 Quality Control

Perform inspection and test works on the materials and revise manufacturing works to ensure that they are in conformity with contract documents.

1-6-2 Technical Staff

1-6-2-1 Execution Engineers

Execution engineers, with the required engineering specializations, shall perform accurate technical direction and revise the quality according to contract documents.

Duties of execution engineer are summarized in the following:

A Takeover, plan, determine axes and directions of the site.

B Prepare the necessary detailed sketches that help in execution of the project.

C Demand the equipments, materials, labor and supplies on suitable times according to time schedules.

D Direct technical supervisors and distribute labor according to work needs.

E Execute all the works according to time schedules.

F Prepare daily reports on work progress and the obstacles that face the execution and methods of their solution.

G Periodic count of the executed works and payments.

H Give directions for better use of the materials, equipments and instruments and their storage on the site.

I Stores supervision.

J Prepare as built drawings.

1-6-2-2 Technical Supervisors

Duties of the technical supervisors are summarized in the following:

A Implement instructions of execution engineers

B Control and direct technical labor.

C Report the obstacles immediately.

D Receive materials and equipments from the stores and settle the custody.

E Maintain the equipments and execution tools and their proper use.

1-6-2-3 Technical Labor

Technical labor shall carry out the works accurately according to the instructions issued from the execution engineers and supervisors.

1-6-2-4 Maintenance and Mechanical Equipments

Duties of maintenance and mechanical equipments unit are summarized in the following:

A Prepare, maintain and operate the equipments.

B Perform periodic maintenance works for mechanical equipments.

C Train the workers on maintenance and operation works.

1-6-2-5 Stores

It performs the following duties:

A Keep store records that show all the supplies, their dates of supply and values and the issued quantities.

B Receive and store all the materials and equipments supplied to the project according to technical principals after completion of inspection and addition procedures.

C Receive the materials and equipments necessary for the works.

D Prepare item cards, their quantities and put them in clear places on the site.

E Demands provision the stores with items that their stock reach to the critical limit.

1-6-3 Financial and Administrative Affairs Unit

It consists from the following:

1-6-3-1 Administrative Affairs

It consists from personnel affairs and auxiliary services.

1-6-3-1-1 Personnel Affairs

It has the following duties:

A Provide the necessary labor required for the work.

B Prepare and follow up workers pay roll

C Prepare production allowance lists according to work progress.

D Prepare and equip the offices and rest rooms necessary for service of all workers in the project.

E Prepare monthly and annual lists on technical and administrative competency of the workers.

F Follow up attendance of workers

G Follow up attendance of workers

H Determine and follow up leaves according to instructions.

I Prepare decisions on transfer and service termination of workers.

J Perform Social insurance procedures

K Issue work permits and complete security procedures, if necessary.

1-6-3-1-2 Auxiliary Services

It includes social and health services.

A- Social Services

It has the following duties:

- Supervise workers welfare fund, where all the workers of the project participate and get benefit from it in the cases that require this.
- Organize recreational, cultural, tourism and religious excursions and field visits to similar work sites.
- Organize different sport activities.

B- Health Services

It has the following duties:

- Prepare health unit for first aids and treatment of injuries and quick cases.
- Transfer injured people with serious cases to the specialized hospitals.

1-6-3-2 Financial Affairs

It consists from the following:

1-6-3-2-1 Financial Accounts

It has the following role:

A- Revise the payments and follow up letters of credit.

B- Perform follow up works and collection from the employer.

C- Prepare record for accounts of suppliers, revenues and expenses

D- Prepare the budget and determine work results.

E- Supervise the purchases.

1-6-3-2-2 Procurements and Stores Accounting

Role of procurements department is summarized in the following duties:

A- Purchase the materials and equipments, ensure their supply to the site on the suitable time and keep regular records in this regard.

B- Report any shortage of supply of the materials and equipments.

C- Calculate delay fines imposed on the suppliers.

Role of stores accounting is summarized in the following duties:

A- Revise the supplies, their prices and quantities according to the contract.

B- Revise notes payable submitted from any department with the approved forms and send them for auditing.

C- Keep a record of stores accounts for comparison with the inventory record.

1-6-3-2-3 Auditing

Its role is summarized in the following:

A- Revise the payments with the count records and conform the rates to the contracts.

B- Revise project financial claims.

1-6-4 Security

It consists from administrative security and industrial security.

1-6-4-1 Administrative Security

Role of the administrative security is to monitor work sites, gates and guard works, including entrance and exit of personnel and equipments, prepare security arrangements to ensure proper and smooth progress of work and revise work permits.

1-6-4-2 Industrial Security

Role of industrial security is to secure the project as follows:

A- Fire resistance, provision and maintenance of the necessary equipments.

B- Secure workers during the work against injuries and work risks.

2- Site planning and preparation

Introduction

The best way to reach the desired goal starts from good planning and analysis of project components to the executive steps prior to the implementation process which create the site to work, including handover of the site, survey the site, preparation, coordination and overall planning and layout of the site including temporary buildings that must be completed before starting implementation of the works so that the project contractor can do the main works easily.

These works are divided into three stages:

A Determination and handover the site, survey works and preparation of the studies.

B Planning, coordination and preparation for the layout.

C Temporary buildings works.

2-1 Determination and handover the site, survey works and preparation of the studies

2-1-1 Determination and handover the site

- Takeover the allocated area of the site from a committee consists of the owner, the consultant, the contractor, representative of the beneficiary body of the project and representative from survey department in the governorate by putting iron fence around the site by representative of survey department.
- Determine the obstacles that hinder execution of the works whether over or under the ground.

- Determine takeover situation of the site “one stage” or “several stages” and date of takeover of each stage.
- Determine water and electricity supplies around the site, if any.

2-1-2 Survey works and preparation of the studies

- Current condition of the site is photographed before start implementation.
- Takeover the bench marks under takeover record signed from owner representative, the consultant and contractor representative after accurate revision of the levels, directions and site dimensions and compare them with the layout drawing to ensure from the correct dimensions.
- Construction of concrete blocks around the bench marks taking into consideration to be away from the excavation area to be hard to removed.
- Perform studies on quarry and workers near from the project to determine the best elements that can be used at least cost.
- The site is divided into net of squares to perform initial network level by preparing sectors of this level to determine excavation cubes, backfilling and leveling.
- Perform the main axes of the site away from the temporary buildings and internal roads of the site.
- Prepare a drawing includes all the obstacles on the site.
- Removal of all obstacles on the site that hinder the implementation process, such as wastes, trees, old buildings, etc.
- Perform the necessary leveling for the site, including excavation and backfilling according to site conditions taking into consideration the proposed implementation methods, project execution level, weather conditions, rain flow directions, etc.

- Perform coordination records with the different bodies before start implementation and the necessary diversions, if required.

- Perform additional soil borings, if necessary according to contract terms.
- Perform geological study to determine the faults and storm water drains.
- Fencing the site and construct a gate for entry and exit of equipments, as well as the Security Office.
- Supply the site with water, electricity, sanitary drainage, communication, etc.
- Perform network level again after leveling and reaching to the design level.
- Study situation of the adjacent buildings and their effect on excavation processes to avoid any cracks and submit report in this regard to the owner to take the necessary actions.
- Issuance of the necessary permits and licenses.
- Select the best places to put project sign in coordination with owner representative and the consultant.

2-2 Planning, coordination and preparation of the layout

Success of any project is measured by allocation of sufficient time for planning and applies implementation methodology as follows:

2-2-1 Studies required for proper planning of the site

The following studies are prepared by project consultant and must be used before start implementation:

- Site, contract terms, project shop drawings, proposed construction methods and plan for the required services.

- Specifications and details of the drawings of the required equipments.
- Time and technical schedules for the equipments, materials, labor, etc. to determine supply periods for project needs in order to decrease the areas used in the stores, losses and motionless items and implement the works on the specified dates.
- Construct concrete mixing station on the site according to implementation conditions.
- Details and requirements of the temporary buildings “Offices, accommodation, stores, workshops, etc”.
- The proposed alternatives in case that site area can not accommodate the temporary buildings, such as rent another lands or administrative units, etc.
- Requirements of industrial security and administrative security in site planning.

2-2-2 Elements to consider when studying perform proper planning for the site

- Effect of wind direction on determination places for welding workshop, storage areas, office building, residential units, etc.
- Effect of rainfall direction, inclination of site land and methods of storage on the ground.
- Motion flow inside employee offices, stores, workshops, etc.
- Determine suitable places for car parking and allocate reception office for visitors.

- Planning of temporary internal roads to facilitate motion of equipments, individuals, raw materials, etc.

  Temporary roads network on the site must be on the same route of the main roads network of the project and not intersect with project constructions.

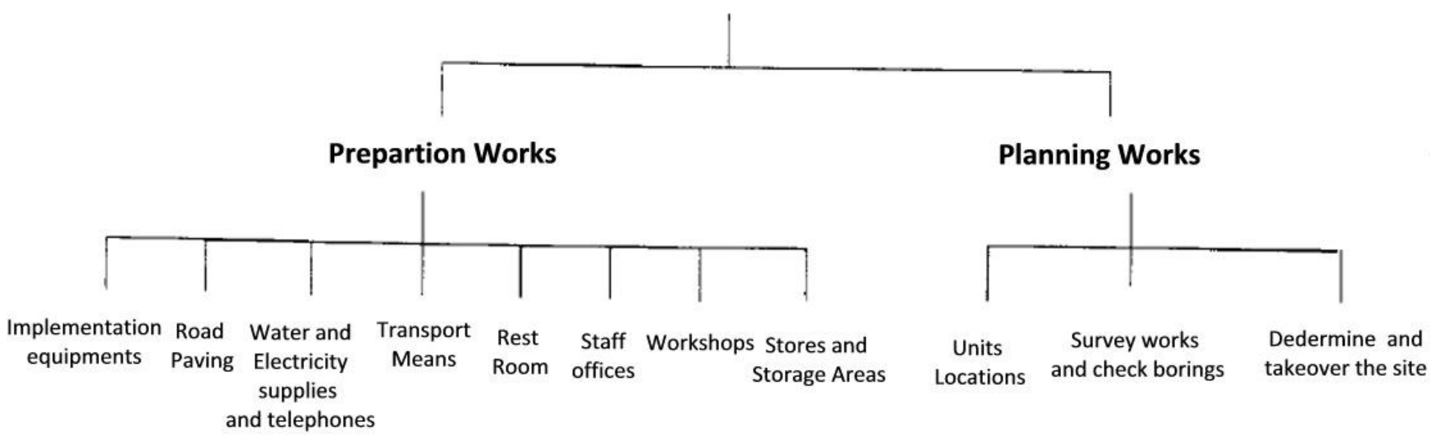
- Take measures to protect the adjacent constructions, such as using dewatering methods and digging piles, poles, etc.
- Provision of places and utilities lines on the site (water, electricity, sanitary, telephones, etc).
- Perform study to analyze well water on the site.
- Determine places for materials storage, including mixing stations and workshops to decrease losses and transport costs. Storage areas must be in places that do not hinder the work and communication inside the site and to avoid storage on excavation areas and reduce as much as possible relocation of stores throughout the project implementation period.
- Raw materials entry cycle for “check, classification and storage” and exit for implementation.
- Study size, motion and height of heavy and fixed equipments inside the site during construction process.
- Provide lighting, guarding, warning signs, banners, etc.
- Equip a laboratory for materials and concrete researches inside the site and fuel station for equipments according to the importance of the project.
- Provide signboards identifying locations of the project “administration offices, rest rooms, visitor’s office, toilettes, unbalance unit, mosque, stores, workshops, working areas, etc”.

2-3 Temporary buildings

2-3-1 Factors affecting construction of the temporary buildings

- Contract terms.
- Wideness of the layout.
- Type of the project.
- Implementation period and time schedule stages.
- Method of construction and type of the used equipments.
- Location of the project “remote or civilian area”.

Fig (3-5): Site Planning and Preparation



3- Implementation of civil and architectural works

Introduction

When implementing civil and architectural works for treatment plant, provisions of Egyptian Code on design criteria and rules of reinforced concrete, soil mechanics, foundations, pipes, etc must be taken into consideration.

3-1 The following conditions must be taken into consideration when designing civil and architectural works:

- Handover, clean and level the site.
- Transfer and remove obstacles (if any) from the site (gas, oil pipes, closed drainage, power lines, etc)
- Revise project documents.
- Prepare place for supervising staff at the site.
- Preliminary preparation according to foundation levels and detailed schedule.
- Revise survey works and prepare survey maps before start implementation with installation of bench marks in fixed and clear places inside the site.
- Start construction of site fence and prepare security procedures.
- Determine entrances and exits and internal road works accessing to the site.

- Determine storage places that do not conflict with project units implementation works.
- The engineer must refer to the designer id any type of soil violates what mentioned in the borings report to give opinion.
- Provide the site with the necessary supplies such as water, electricity, telephone, etc.
- Provide the site with materials, substances and equipments necessary for the constructions.

- Must take into consideration technical principals of storage and conformity of the supplied materials and equipments with the samples and the approved specifications.
- The site must be provided with the necessary devices for taking samples and design of mixtures to perform the tests on the materials and breaking the cubes.
- Design standard mixture of the storages exists on the site and determines percentage of the stress corresponding to maximum required stress according to shop drawings.
- Locate the axes and plant unit's places on the ground according to shop drawings.
- Perform sequence and technical coordination in achieving work items related to each other (civil, mechanical and electrical works) and avoid conflict or difference between them.
- Perform foundation exaction works, pouring concrete, control ground water level, if any, through follow up of its levels daily through monitoring wells. Also, revise levels of low water level during implementation of works, and case of unexpected decrease in these levels, must return to the designer to take the suitable steps to avoid any effects or dangers that may be resulted.

- Treatment of the places of pullers on the underground installations.
- Must use formworks that provide fair face. Fig (3-6) and Fig (3-7) show model for these formworks.

- Must implement ducts and trenches for electrical cables do not intersect with pipe paths and channels with the required dimensions according to drawings.
- Check places and method of operation of water stop and keep them during pouring to avoid their damage or change their places.

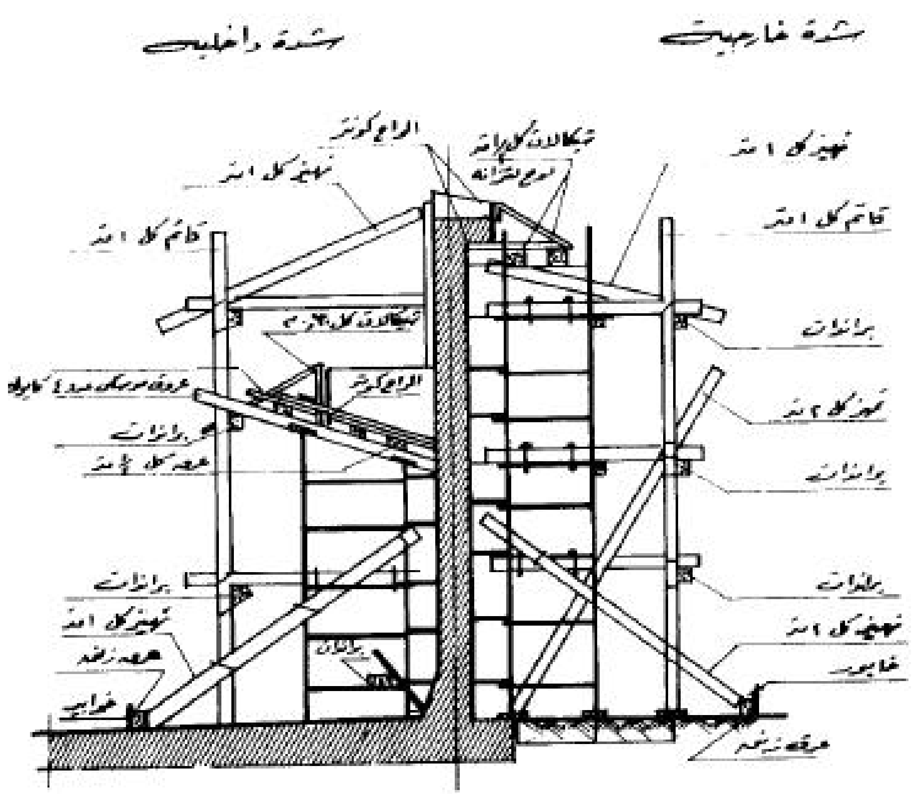


Fig (3-6): Formworks of a weir give fair face

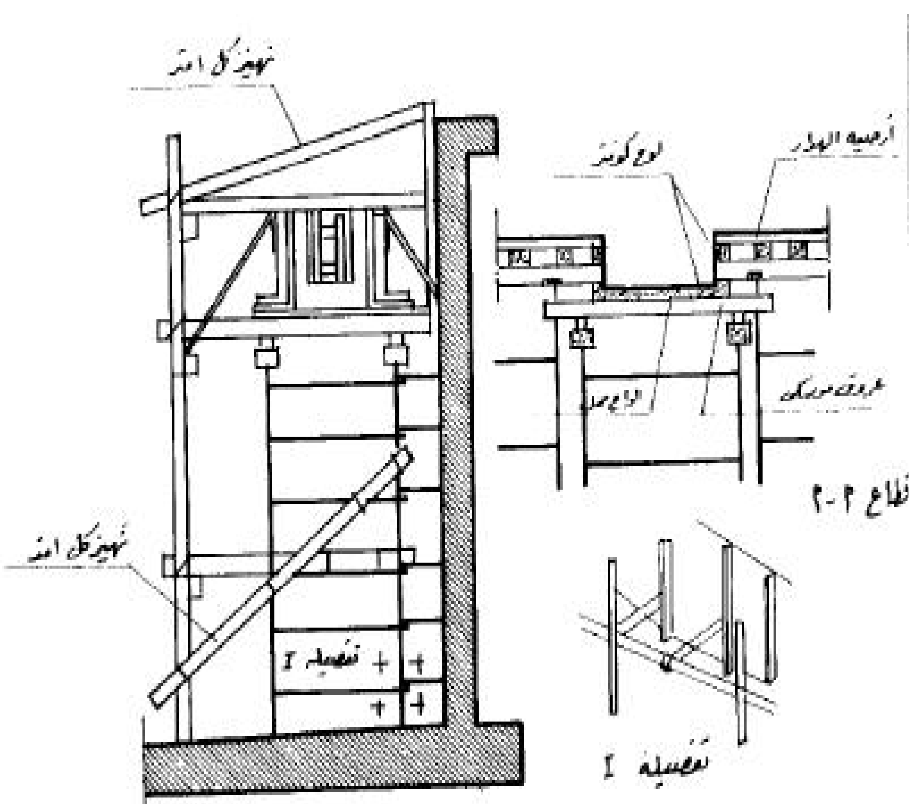

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Fig (3-7): Formworks of a weir give fair face

- Pouring spacing must be cleaned according to the shop drawings and Egyptian Code on reinforced concrete.
- Pins of the crawlers, screens, gates and all buried parts must be fixed and puddle pieces must be installed before pouring reinforced concrete such that wall washer is installed at the middle of wall before pouring.
- Care of rounding concrete edges of tank heir and their linearity and to adjust their levels using right scale and must be tested after completion of works by observing exit of water from all holes with equal and regular flow according to the hydraulic levels.
- Care must be taken to implement path for bridge wheels of tank sweepers at fixed level to avoid friction between sweeper wheels path and the concrete, also the walkway must be implemented at this path using anti- wear and friction materials.
- Check inlet and outlet levels for all units.
- Must take into consideration places of holes and bases of mechanical and electrical equipments.

To keep the life span of the water concrete constructions, they must be insulated as follows:

A- Internal insulation only if the construction is over groundwater level.

B- Internal and external insulation if the construction is at the level of the groundwater,

- Follow the schedule and notify the contractor in case of any delay of inconformity of any work with the specifications to avoid the delay and continue the work according to the schedule.
- Prepare and perform the final drawings for the layout according to as built drawings.

4- Implementation of mechanical and electrical works

4-1 General Conditions

When implementing mechanical and electrical works for treatment plants, the following elements must be taken into consideration:

4-1-1 Before installation:

A. Revise the implemented civil works to ensure from the design dimensions according to the shop drawings, levels, inclinations and all civil finishing works as mentioned in the drawings and specifications of these works.

   Also, care must be taken to revise dimensions and axes of the holes and their levels and the necessary requirements to achieve them and install mechanical equipments through these holes according to shop drawings of mechanical works.

B. Supervise implementation of equipments according to the dimensions specified by the manufacturer according to catalogues and the approved drawings, and must take into consideration to use the materials according to instruction and to adjust level of the surfaces.

C. Clean tanks, channels and all civil units form any remaining construction and building works during implantation.

D. Revise quantity and quality of the mechanical equipments and compare them with the supply order in terms of model, serial number, country of origin, inspection certificates, test certificates and make sure of the components and parts of the mission and compare them with bill of quantities and mechanical detailed drawings.

E. Visual inspection of the equipments to check existence of breakage or damage occurred during transportation.

4-1-2 During installation

A. Develop steps for equipments installation for each unit, taking into consideration to arrange installation of equipments with respect to each other, such that installation works for pumping equipments start first (cranes), then the equipments installed at the lower levels, then the upper one, and so on. Also, must follow instructions in suppliers and manufacturers manuals.

B. Must take into consideration to adjust axes levels of the equipment before pouring their bases and to implement the connections between equipments.

C. Must check correct installation of valves in terms of direction of open and close, their order and directions (arrow direction on the valve)

D. Check all parts required to be lubricated and to use oils and grease according to manufacturer instructions. Must also check electrical connections between mechanical equipments and control boards.

E. Check adjustment of inlet and outlet levels of the units as well as adjust outlet heirs using right scale.

4-1-3 After installation

- After completion of installation works and before start operation, each equipment must be operated for short time to insure direction of motion.
- Test experiments are performed on the site as indicated to tests section.
- Operation period for performance tests must be started without stop for at least 72 hours, in case of completion successfully without problems or obstacles, preliminary handover report shall be issued and then warrantee period is calculated for these equipments from this date.

4-2 Conditions of installation Mechanical and Electrical Equipments

4-2-1 Pumps

- Before installation of the pumps, must ensure at first, fitness of the pumps after shipment and transportation to the site and non-existence of breaks or cracks on the pump body or any defects in any part thereof.
- Must conform the data listed on the data tag of the pump to the data and specifications stipulated in the contract.
- It is necessary to obtain full information about correct installation of the pump, including all details of the pipes, corresponding water levels, maximum and minimum operating conditions from pump manufacturer manual. Pump base must be implemented according to instructions of the manufacturer and if it is necessary to make a layer (structure) of steel sections, the measurements must be adjusted and keep a degree of levelness and take into consideration level of the concrete base on which the steel structure will be installed.
- Must give great care for alignment of the axes to reduce periodic maintenance works for the glands, and by using flexible coupling, effects of misalignment can be avoided.

- In all cases, must follow manufacturer instructions when align the axes to avoid usage of axes bearings which have rapid corrosion and damage.
- Pump must not be used as a tool for fixing the pipes and care must be taken when installing pipes and valves system for the pumping station and ensure that there are no strains transferred to pump nozzles (due to misalignment) which causes clutching of the pump or breakage of the parts made from castings.

- Position of the pump (mounting level) with respect to the suction water level must be taking into consideration and existence of separate suction pipes for each pump in case of multi-pump stations.
- If it is necessary to execute common suction line for the pumps, must take into account that maximum hydraulic inclination of the suction pipes occurs at maximum operating conditions and not to decrease the pressure in the common suction pipe at any point less than the value at which the pump is at the standby position under suction pressure less than the atmospheric pressure and leads to be escaped through the glands and the pump becomes air locked and unfit for operation where it needs reset.
- Must take into account the allowed percentage of suction pipe reducers.
- Suction pipes must be put inside the sump and ensure that their levels are in accordance with the design, as uncover of the suction nozzle with appropriate minimum level leads to formation of air bubbles enclosed inside the pump and causes lose of priming while the pump is running.
- Must avoid existence of high suction pressure on the pump whether by changing its mounting level or using high friction pipes or existence of blockage at the suction side whether at the suction inlet or existence of gate valve not

completely open and leads to confinement in the pump and cause wearing for pump metal surface due to formation of steam sinuses inside the liquid and accumulate on the solid surfaces of the pumps.

4-2-2 Electrical Motor

Before installation, must inspect the motors and make sure that they are not damaged due to improper storage for long periods.

- Motor must be clear of any symptoms of corrosion before installation.

- Resistance of motor windings must be measured by megger device to ensure that they are not affected by humidity during storage. The resistance must not less than 1 Mega, and if it is less than this value, the winding must be dried and re-measured again.
- Ratings of the motor must be checked and compared with the data tag and supply documents.
- Must make sure that the place of motors installation is safe and is not subject to fire, risks or corrosion conditions except if the motors are designed to operate in these conditions.
- Must remove any dust or deposits on motors parts before installation and check fulcrums, connection points and slip rings to ensure their fitness and not being subject to corrosion or cracks.
- Must check motors bearings grease (except the sealed types and those designed to work over life span of the equipments) and ensure their fitness or replace it if necessary.
- Motors must be mounted on solid and flat base to avoid vibrations. Usually, the base consists of a bedding from steel sections mounted on reinforced concrete

sill taking into account to be the tying screws carefully commensurate and to assemble the bedding such that the surface is flat and their axes are aligned when putting on the concrete sill and sealing of the bedding after leveling and alignment.

- If the cost of the bedding is high, the motor can be mounted directly on the concrete base using wedges inserted in the concrete, usually from cast iron with smooth top and longitudinal reduced hole and cracks on the body to ensure good cohesion with the concrete. Wedges are tied with motor legs and the motor is mounted on the concrete base for proper adjustment. Permanent mortar cement is used for sealing. After final adjustment and leveling, holes are punched in opposite direction of motor leg inside base wedges and insertion of pins to facilitate re-installation works of the motor on the base.

- Simple adjustment, height adjustment or motor replacement can be achieved by using shims under motor legs.

  Doweling is also used after sealing (alignment) and final adjustment of the motor in case of using steel bedding.

- Large motors with axes mounted on a manufactured base usually have bedding with lower structure from cast iron to be mounted directly on the reinforced concrete bases prepared for this purpose.

- Motors with flanges or vertical motors are installed usually on lower structure. Vertical motors are mounted on pre cast skirts especially for driving the pumps and are considered motor stool.

4-2-2-1 Alignment

- Fine adjustment is the main requirement to avoid faults of bearings and couplings. Alignment is performed between the motor and the pump before tying the joints.

- Faces of the joints must be in parallel and to take into account any spacing between the faces recommended in manufacturer instructions.

- Alignment is finally performed for the joints and revised using pointer meter.

- Double bearing motors are connected with the pump by flexible joint to decrease transfer of shock loading to bearing.

- Single bearing motors are connected with the pump by using solidly bolted joint and not flexible joint because these motors are not designed to withstand downward thrust resulted from rotor weight.

- Mechanical mounting of the motor is completed when the two halves of the joint are connected. It is required more inspection before supply the electrical current and to make sure that the motor cooling air is flowing without obstacles whether from the air inlets or exhaust outlets, as the insufficient space between air inlets and the adjacent walls leads to temperature increase.

- Must ensure that all covers are removed and any gates must be kept open during motor operation.

- All auxiliary equipments must be checked and properly fixed, such as air compressors, rpm meter, external coolers, filters, bearing vibrations or temperature probes and bearing oil circulation equipments.

- Must test cross section areas of motors power and control cables and conductors according to the design and to check and compare the operating voltage with the design.

- Must check cable terminals to ensure that they are properly connected for good conduction of electricity.

- Must connect earth screws carefully with the motors according to instruction of the competent bodies, applicable regulations and manufacturer proposals.

- Must adhere with safety rules, fire and explosion risks prevention.

4-2-2-2 Start Motion

- After installation of motors and proper connection of their cables, addition check is performed to insure that the bearing is good greased, efficient operation of the cooling system, air inlet and outlet without any obstacles and the electrical current is connected to all ventilation fans with separate drive to ensure they are rotating in the correct direction.

- Must ensure that motor cooling fan is rotating in the correct direction according to the specification illustrated in the connection circuit with respect to motor rotation as indicated in motor data tag or on motor body.

- After initial check of the motor after installation, operation and loading of the motor, the necessary inspection must be performed to ensure from vibration rate, monitor and control reading of speed and measuring meter.

4-2-3 Motor Control Center (MCC)

- Before start installation works, must revise manufacturer drawings and compare them with contract drawings.

- Must inspect location of installation of MCC and its relation to cable trenches and paths.

- Must carefully plan for future cables installation before installation of MCC.

- If MCC is of floor mounted type, must provide with flat base.

- Must take into account total height of MCC and compare it with building height and upper cable trays.

- Must take into account ventilation of MCC in order that MCC is working in low temperature and decrease vapor condensation inside it.

- For performing preventive and periodic maintenance and to facilitate troubleshooting, must take into account easy access to MCC when putting the equipments.

- MCC must be installed in places with low vibrations and to be fixed vertically and firmly in order not to affect MCC components. Screws, nuts and terminals must by firmly tied before operation of MCC. Before connection of the motor with the control panel and starter motion, must ensure their capacity according to data tag for each of them.

- Cable terminals (power and control) connected and going out from the MCC must be marked according to the numbers indicated in the detailed drawing of MCC to facilitate and ensure correct connection.

- Cable paths must be kept away from any hot parts or bodies such as heater grids and resistance block, and if it is difficult to avoid this, must use heat resistant cables.

- Must be cared not to scratch the cables by sharp tools such as iron tools, screws, etc.

- When laying the cables, must adhere with the specified number according to design drawings to prevent over heat that affects cables efficiency.

- Must put marking, warning and safety tags and different covers after installation.
- Must earth all parts of MCC.
- Before connection of the electrical current, must take the necessary steps:

* Perform insulation resistance test for all terminals and distribution bars and to isolate or disconnect measuring and control devices before apply the high tension.

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* Operate all the magnetic devices manually to ensure that all the moving parts are working freely.

* Revise electrical connection terminals to ensure correct and safe operation.

* Disconnect the temporary connections that required for transport of the boards (or any fittings) for the bridge connected on current transformers.

* Revise ratings of the relays on the actual loads of the MCC according to data of the working motors connected on MCC.

- Revise operating times for the timing devices.
- Clean all internal parts of MCC.
- Test operation of all control and safety (protection) circuits.

4-2-4 Transformers

- Before installation, transformers must be checked to ensure that there is no fault or breakage resulted from transportation. For oil transformers, must check oil level and any leakage.
- Must check painting of the transformers and note any defects.
- Must check transformer terminals and note any mechanical defects.
- Must check the connections and windings and note any defects in the insulation.
- Must carefully check resin of the dry transformers, as it is easy to be scratched or cracked and ensure there fitness before installation.
- For oil transformers, must provide passes for the leaking oil for collection of the leaking oil taking into consideration possibility of occurrence cracks or holes affecting main tank of the transformer.
- Shape, size and type of the materials used in construction of the transformer enclosure are determined according to rate of disposal from the heat resulted from the fire of transformer oil.
- All types of dry transformers must be installed inside the buildings and surrounded by metal frame connected with the earth (or metal grid barrier).

4-2-5 Distribution Panels

- Before installation, must ensure existence of the drawings and instructions issued from the manufacturer of these panels that give directions for installation.

- Must ensure that the chamber in which the boards will be installed is clean and dry and to remove any existing wastes.

- Must close and cover any unused cell in the board that may left for emergency.

- Must keep all insulations in the board clean and dry and cover them during installation works.

- Must use the correct method of handling and mounting must be on the points specified by the manufacturer in order not to subject any parts of the board to stresses or sudden load that may lead to damage or defects to board body or its components.

- Proper installation of the boards and safety of operation depend to a great extend on accurate implementation of the bases of the boards.

- The best method for implementation if distribution boards bases are the steel sections shaped in the form of channel buried under the ground below the boards and provided with screws (bolts) and nuts and must take into consideration that these sections are parallel and leveled and little jut out over the level of the floor surrounding the boards.

- The board is installed on the base by direct mounting on the steel structure of the base after being leveled.

- Base steel structure can be replaced by bolts put inside pits prepared during pouring of the board's chamber flooring and the bolts are put inside it and then perform sealing around them and then the boards are installed and fixed by these bolts and their suitable nuts.

- If the switchboards are supplied in parts to be assembled at the site, middle parts are installed first then the sides to ensure non-accumulation of mistakes that can not be noted in case of non-matching between the different parts of the board. Water pipe is used to ensure alignment of the board parts during assembly, taking into account to leave the screws between the parts untied until completion of parts assembly.

- After installation of the board, must check and ensure that all the movable components of the board can be easy removed and also easy open and close of the doors and covers of the board cells.

- Devices and components supplied disassembled must be inserted in their specified places to be maintained during transportation and then connected after installation and mounting of the board.

- When connecting the cables to and from the board, must avoid any severe bending or squeezing of the cable. Cable terminals must be installed in a way that not allow for any stresses or excess tension on the cable terminals after connection, taking into consideration maximum diameters of bending for these cables according to the measurements determined in the standard specifications.

- Earth of each board must be connected to all metal parts in the boards, enclosures of the measuring instruments and earth points of the switches through tying or riveting and never by welding. Earth wire must be continuous and fixed firmly with the main earth through tying or riveting also.

5- Tests

All materials and equipments used in construction of the pumping stations are subject to tests necessary to ensure their fitness for use and their required purposes.

These tests are divided into two parts, one is performed inside production facilities and the other is performed in implementation sites.

The following are types of materials and equipments required to be tested inside production facilities and implementation sites.

5-1 Materials

They include sand (small aggregate), pebble (large aggregate), cement, mixing water, pipes and fittings, lime, gypsum, insulating materials, stones, tiles, marbles, granite, painting materials, chemicals, asbestos, wood and glue, glass, iron sections, aluminum sections, welding materials, screws and accessories, laid grids and wires, construction partitions, ceramics and faience, rubber products, vinyl flooring, cork, metal and non-metal plats, steel sections, hoses, paving materials and metal products and their alloys.

5-2 Architectural accessories

They include hinges, lockers, handles, latches, faucets and valves.

To test the materials and equipments inside the factory or in the places of extraction, the owner or his representative shall monitor the manufacture process, if necessary, whether at the workshops of the contractor, factory or quarrying from which the contractor obtain these materials, and he has the right to enter and remain in these places during manufacture or extraction of these materials.

5-3 Equipments

They include motors, pumps, generators, cables, distribution and control boards, valves, cranes, measuring and alarm devices, gates, transformers, conveyors, screens, protection devices, tools, control devices, workshop instruments and fire fighting equipments.

These tests are performed at the expense of the contractor to ensure that each part of these equipments is manufactured according to Egyptian standard specifications for the equipments manufactured in Egypt, and according to terms and conditions of the contract. For the equipments imported from abroad, the engineer or his representative shall present at manufacturing facilities for accurate inspection. The contractor shall notify the owner by the names of the factories, workshops and suppliers from which shall obtain these materials before start in the works trusted to him. The contractor shall submit certificates from the approved inspection committee for the imported equipments from abroad and it is not allowed shipment of any equipments or supplies without being inspected by owner representatives.

The contractor shall provide the owner with copy of the drawings and specifications approved for this purpose and the owner is authorized to test theses equipments and supplies which will be supplied by the contractor according to contract conditions. The owner is entitled to reject any equipment that are not in conformity with the specifications and shall approve the inspected samples and put discriminated mark to prove that they are passed the tests successfully and on the basis of them the equipments will be supplied to the site.

5-3-1 Equipments test at production facilities

- These tests are performed for all equipments that are contracted to be supplied before transportation from the contractor or producer factories.

- Different equipments shall be installed and operated (to the most possible extend) according to actual operation conditions at the work site.

- Mechanical equipments that are driven by electrical motors must be tested on the same motors except if the operating voltage of these motors is not available in the production factories or contractor test laboratories. In this case, tests can be performed on typical motors and the available calibration for such tests taking into account to calculate the actual consumed powers to ensure operation of the equipments when being driven by their motors at work site with the same efficiency and accuracy.

- The above item is applied in case of different measuring instruments that must be used to calculate the measurements of the mechanical equipments which shall be supplied for the project, if possible.

- The measuring instruments used in performing the tests in production facilities must be calibrated and to check the supporting certificates from the certified bodies in the manufacturing country, taking into consideration ratings accuracy and compare it with the accuracy indicated on the data tag from the producer.

5-3-1-1 Hydraulic Pressure Tests

All castings, valves, pipes, special pieces and any other pieces in the equipments subject to pressure must be tested under a pressure equal to double maximum pressure designed for the work.

5-3-1-2 Tests of materials and apparatuses

All materials used in the manufacture and any apparatuses necessary for the equipments must be tested according standard specifications of the producing country or to international standard specifications ISO and to obtain approved certificates from the competent bodies.

5-3-1-2-1 Mechanical Screens

A- Revision and approval of execution documents.

B- Steel manufactures

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Inspection of surface treatment against external effects.

C- Assembled parts (materials and components)

- Visual inspection of the assembled parts and their dimensions.
- Electrical and mechanical test (try installation at the workshop).

D- Electrical motor and gearbox

- Revision of conformity certificate.

- Inspection of dimensions and paintings

- Running test.

E- Before shipment

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

- Revision of final dossier.

5-3-1-2-2 Sand sediment (removal of oils , crawler bridges)

a- Design documents

- Revision and approval of the documents.

B- Steel manufactures

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Visual inspection of the manufacturers and their dimensions
- Inspection of surface treatment against external effects.

C- Assembled parts (materials and components)

- Visual inspection of the assembled parts and their dimensions.

D- Complete assemble of upper bridges

- Visual inspection of the assembled parts on the upper bridges and their dimensions
- Performance inspection at no load (electrical and mechanical parts, operation, adjustment and control)

E- Electrical Motor and gearbox

- Revision of conformity certificate

F- Rubber Scraper

- Revise materials and their dimensions

G- Before shipment

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

5-3-1-2-3 Primary Sedimentation Bridges

The following measures shall apply:

A- Deign documents revision

B- Steel manufactures

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Visual inspection of the manufacturers and their dimensions
- Inspection of surface treatment against external effects.

C- Assembled parts (materials and components)

- Visual inspection of the assembled parts and their dimensions.

D- Complete assemble of upper bridges

- Visual inspection of the assembled parts on the upper bridges and their dimensions
- Performance inspection at no load (electrical and mechanical parts, operation, adjustment and control)

E- Electrical Motor and gearbox

- Revision of conformity certificate

F- Over flow weir sheet

G- Rubber scraper blade

H- Scum board sheet

I- Shop run test assembled drive unit

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

5-3-1-2-4 Surface aeration turbines

A- Deign documents revision

B- Impeller cone

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Static balancing inspection
- Surface treatment inspection

C- Drive Shaft

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Visual inspection of drive shaft and its dimensions
- Static balancing inspection
- Surface treatment inspection

D- Assembled parts (Drive shafts, impellers and drive units)

- Visual inspection of the assembled parts and their dimensions and try to install them in the workshop

E- Gearbox

- Revision of conformity and test certificate
- Revision of dimensions and painting

F- Electrical motor

- Routine test

G- Before shipment

- Final visual inspection and revision of markings and ensure fitness of equipments sealing
- Revision of final dossier

5-3-1-2-5 Final sedimentation bridges

As in item 5-3-1-2-3

5-3-1-2-6 Sludge thickeners

A- Deign documents revision

B- Steel manufactures

- Revision of manufactured materials certificates.
- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Visual inspection of the manufacturers and their dimensions
- Inspection of surface treatment against external effects.
- Drive test in the workshop

D- Assembled parts (Drive shafts, impellers and drive units)

- Visual inspection of the assembled parts and their dimensions
- Try to install them in the workshop

E- Gearbox and electrical motor

- Revision of conformity and test certificate

F- Weir plates

- Revision of materials and their dimensions

G- Rubber scraper blades

- Revision of materials and their dimension

H- Before shipment

- Final visual inspection and revision of markings and ensure fitness of equipments sealing
- Revision of final dossier

5-3-1-2-7 Chlorine equipments

A- Chlorinators

- Revision of manufactured materials certificates

B- Measuring and control devices

- Revision of manufactured materials and calibration certificates

C- Leak detector

- Revision of manufacturer certificates.

D- Pumps and fans

- Revision of conformity certificates

E- Before shipment

- Visual inspection of painting
- Visual inspection of all parts and their dimensions
- Final visual inspection and revision of markings and ensure fitness of equipments sealing
- Revision of test reports.

5-3-1-2-8 Penstocks

A- Revision of execution documents.

B- Revision of the materials for (gates, frame, shaft and seating)

- Examining materials certificate

C- Installation

- Visual inspection of welding and their dimensions.
- Inspection of 10% of LP/MT welding.
- Visual inspection and dimensions
- Inspection of surface treatment.

D- Assembled Parts

- Visual inspection of the assembled parts and revision of their dimensions.
- Performance verification.

E- Before shipment

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

5-3-1-2-9 Electrical Motor Test

Motors are inspected according to the following particulars and properties:

- Implementation.
- Manufacturing and finishing

- Main dimensions.
- Air gap measurement
- Paintings
- Correctness of documents.

These particulars are compared with specifications, drawings, accepted bid, codes and standard specifications.

The following routine tests are performed for the motors:

- Measurement of windings cold resistance.
- Measurement of cold insulation resistance (megger test)
- Measurement of detectors cold resistance (if any)
- Measurement of open circuit voltage of the rotor.
- No load properties.
- Closed circuit properties
- High voltage test (Dielectric test)
- High voltage test is performed according to the voltage specified in the standard specifications for both stator and rotor.

The following performance tests are performed for the motors:

- Hot drive test.
- Load and efficiency properties.
- Over current test.

- Break down torque.
- Warm insulation resistance test (by megger).
- Pulse test for stator windings voltage.
- Inspection of radio interference.
- Inspection of vibrations and noise level.
- Measurement of motor resistance.
- Measurement of GD.
- Mechanical test.

Motor withstands over current for 15 seconds at least without sudden change in speed (under credit torque increase) at maximum torque of at least 60% over this corresponding to full load rating.

The following inspection and tests are performed for rotor starter at the factory:

- Same inspection items as mentioned in the motors.
- All starters are subject to performance and high voltage tests.

5-3-1-2-10 Tests of electrical distribution boards (assembled)

Inspection is performed for the following:

- Acceptance test for manufacturing and assembly.
- Revision of dimensions.
- Paintings.
- Revision of connections and wires.
- Correctness of documents.

- These items are compared with specifications, drawings, accepted bid, workshop drawings, codes and standard specifications.

- The following tests are performed for the boards:

- High voltage test.

- Performance safety for the following:

Operation- Control and protection circuits.

5-3-1-2-11 Generators

A- Preliminary inspection

- Revision of motor test certificate.

- Revision of generator test certificate.

- Revision of electrical control devices test certificate.

B- Group trial test

- Visual inspection and dimensions.

- Load test.

- Over load test.

- Speed regulation test.

- Voltage regulation test.

- Inspection of functional parameters.

- Inspection of clutched starter and components.

C- Before shipment

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

- Revision of final dossier.

5-3-1-2-12 Submerged Pumps

- Revision of routine test certificates
- Performance test

(Flow- head- speed- motor power analysis- efficiency- functional diagram- vibration- materials- paintings and surface treatment)

- Visual inspection and dimensions.

- Inspection of indicators panel.

- Inspection of documents and sealing.

5-3-2 Equipments tests at site

5-3-2-1 Water constructions impermeable test

Water constructions are tested to know there resistance to water permeability before being insulated by filing them by water to the specified height. The test is acceptable if there is no infiltration on the external surfaces and to observe the dryness of the tanks for seven days, then observed again for another seven days. At the end of second week, if there is no water leakage and the water level did not decrease more than 3 mm during the last 24 hours, the test is acceptable.

When measuring the level, must take into consideration losses by evaporation which must be measured by approved devices.

If conditions of test are not fulfilled, test period shall be extended to another seven days. The test is acceptable if the conditions are fulfilled.

In case of water leakage, it shall be immediately treated using sealing compounds with the approved methods.

5-3-2-2 Hydraulic Test

Treatment units are tested at the site from beginning of water entering until coming out to disposal places to ensure from hydraulic levels during operation of mechanical and electrical equipments of all plant units.

5-3-2-1 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.

5-4 Tests at site

5-4-1 Eletrical Motors

Reliability test is performed for the motors at site by driving the motor at full load for 10 days and any changes or adjustment are not allowed during the test.

Motors must be rotated freely without existence of any vibrations and the temperature of each part of the motor must be within the specified limits according to original design of the motor.

5-4-2 Electrical distribution boards

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

- Inspection of external interconnections.
- High voltage test
- Ensure performance safety according to check list indicated in item 5-3-2-6-1.

5-4-3 Electrical Cables

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

- Testing insulation my MEASURE by using 500 volt 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.

5-4-4 Pumps

The following operation tests are performed for the pumps after installation to ensure correctness of installation according to implementation conditions for a period not less than 24 hours of continuous operation.

5-4-4-1 Pumps installed on dry well

At the end of the specified operation period, must ensure that the pumps have passed the tests satisfactory without any problems and to measure the following parameters and compare them with warrantee tables for these pumps:

- Consumed power at different operating points over the approved operation range.

- No existence of any wears on the impeller or pump shaft.

- No existence of any vibrations or abnormal sounds at any operation point including stop point of the pump.

- Measurement of bearing temperature for the pumps and connection shafts and compare them with the standard values shown in the supplier catalog and the approved technical data of the pumps.

Suitable measuring instruments are used to record these readings. The measured vibrations (peak to peak) at any point of the equipment must not exceed 0.10 mm.

5-4-4-2 Submersible Pumps

For this type of pumps, operation test is performed twice, the first in air (without submersion in water) and the second after submersion. In the first case, water level inside the sump is kept under pump motor level. In the second case, the water level covers the motor completely during the operation period.

The following parameters are measured and compared with warrantee values for the pumps according to the contract:

- Motor temperature increase.
- Electrical power inlet to the pump and measured on the control board.
- Inspection of the bearing and mechanical seal and ensure non existence of wear or corrosion.
- No existence of vibrations or abnormal sounds during operation period and over pump operation period including stop point and to use the necessary devices for record.

5-4-4-3 Screw Pumps

After installation and lining of suction and operation screed, the same tests of the vertical pumps installed on the dry well are performed and the readings are recorded and compared with the warrantee values approved for these pumps.

5-4-4-4 Mechanical Screens

After installation and adjustment of screens according to implementation conditions, tests at site are performed to ensure that the entire screen as a mechanical system, including means of protection, is designed to withstand the subjected torque and the protection means are worked to avoid any faults for the screens due to load that exceeds the rating power of the electrical motor and driving unit.

5-4-4-5 Treatment unit's equipments

All treatment units' equipments must be operated continuously for 3 days and observe the following:

- No existence of vibrations or abnormal sounds at any part of the equipment and must be recorded by suitable measuring instruments. Vibration displacement must not exceed 0.10 mm at any part of the equipment (peak to peak)
- Calculation of rotational speed and linear speed of the equipments and compare them with warrantee values in the contract.
- Apply overload on the equipments and ensure that all protection devices are working efficiently according to warrantee values.
- Measuring the temperature at all bearings and compare it with the values in the operation catalogs and manufacturer data.
- Measuring the deflection in the meal bridges and compare in with warrantee values.
- Observe and measure outlet heir levels.
- Check existence of any corrosion or wear at any part of the equipment in contact with concrete constructions of the treatment units.
- Check operation of limit switches, reverse motion and fitness of overload protection devices.

5-4-5 Electrical Switchgears

5-4-5-1 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.

5-4-5-2 Measurements

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

5-4-5-3 Inspection of the following:

- Cables and bus bars.
- Earthing equipments.
- Measuring and protection devices.
- Fittings of bus bars.
- Voltage and current transformers.
- Marking of the electrical circuits
- Cleaning of cells and devices.
- Motion of switches and relays.

5-4-5-4 Equipment Tests

5-4-5-4-1 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.

5-4-5-4-2 Transformers Test

The following tests are performed for the transformers:

- Measurement resistance of all windings at the rating load and maximum position of tapping.
- Ratio test for all tapping positions.
- Poles and phase relation test
- Load loss at the rating voltage and impedance voltage.
- Induction current at rating voltage.
- Voltage test
- When testing winding insulation, induction voltage is tested over the nominal voltage at increased frequency.

Additional Tests:

- Pulse voltage
- Noise level
- Temperature rise
- Insulation test at high voltage for cables and bus bars.
- Twisting test on the bus bars.

- Test ON and OFF of switches.
- Test of relays controls and prove the accuracy.
- Test energizing of the relays.

- Test of indicators and warning lamps of the measuring instruments.

6- Performance and handover Tests

Introduction

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

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.

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.

6-1-1 Equipments Performance Test

A- General Conditions

- All mechanical and electrical equipments supplied and installed in different units of the plant are inspected and compared with contract requirements and ensure their installation with all accessories according to the shop drawings, tender conditions and specifications and the contract made with supplies and installations contractor.
- Make as built drawings including any amendments by decrease or increase according to instructions of the consultant or owner representative and approved from project consultant.
- Ensure handover of the spare parts supplied for each equipment by a detailed list and fitness of these spare parts and their storage according to technical principals.
- Submit O&M manuals for the units.

B- Electrical tests before operation and connection of the current supply

- Insulation tests by megger

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

- High Voltage Test

- All electrical equipments (motors, cables and distribution board components) are tested by calibration device transferred to the site. The test is performed by a voltage according to the standard specifications and not less than 1000 volt and measurement of the leakage current and verifies the standard result at site and their conformity with standard conditions, specifications and allowed limits.

- Control circuits tests

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

- Distribution board protection devices test

Protection devices installed on the distribution boards are tested according to following:

- Short circuit
- Voltage increase and decrease
- Missing of any phase
- Direction change.

In addition to any other protection tests mentioned in tender specifications such as suction level decrease for the pumps and any other details.

- Earth resistance measurement

Earth resistance is measured by calibrated ohm meter. Earth resistance must not exceed 2 ohm/m except otherwise mentioned in tender specifications.

C- Tests after connecting electrical current supply

No load test

Flexible joint between the motor and the equipment is removed and the motor is operated at no load for 3 continuous hours and measure no load current, motor vibrations, temperature and rectification time.

Full load test

Flexible joint between the motor and the equipment is connected and perform alignment.

The motor is operated at full load for at least 24 hours / pump and measure the following:

- Rectification time by using timer.
- Test of over load protection devise and adjust it for full load. (motor rated power)
- Test of short circuit device and adjust it on 10 times motor nominal current.
- Measure of motor temperature over operation period for 24 hours.
- Measure of power factor using power factor meter.
- Measure vibrations of both motor and equipment.
- Calculate the difference value between motor power and maximum power of the equipment (service factor) and compare it with tender specifications.
- Measure and calculate total efficiency of the unit as well as electrical current consumption rate and compare them with design rates according to tender specifications

D- Pumps test

Flow and head are measured at the following points:

A- Operation when closing discharge valve fully and measure the head at zero flow of the pumps for only one stage.

B- Operation at duty point through control of the discharge valve and the flow is determined at this head.

C- Operation at maximum open of the discharge valve such that the value does not exceed motor rated current and adjust maximum control of discharge valve open at this limit.

2-1-6 Preliminary handover tests for plant units

A- Primary sedimentation tanks

Tanks must be operated continuously for 3 days at lease and measure the following:

- Sedimentation efficiency

Removal 50% at least of the suspended solids measured for the water coming to the tanks.

- Measure BOD_5 of the water coming out from the tanks.

Removal 35% at least from BOD_5 of the water coming to the tanks

B- Filters

Each filter must be operated for 3 days at least and measure the outlet flow.

C- Aerators

Each aerator shall be operated continuously for 3 days at least and measure the following:

- D.O. : Not less than 2 PPM

- Concentration of solids according to the applied system for aerators.

D- Final sedimentation tanks

The tanks must be operated continuously for 3 days and measure the following:

- Sedimentation efficiency
- Measure BOD_5 of the water coming out from the tanks.

The output wastewater must be in conformity with the governing laws.

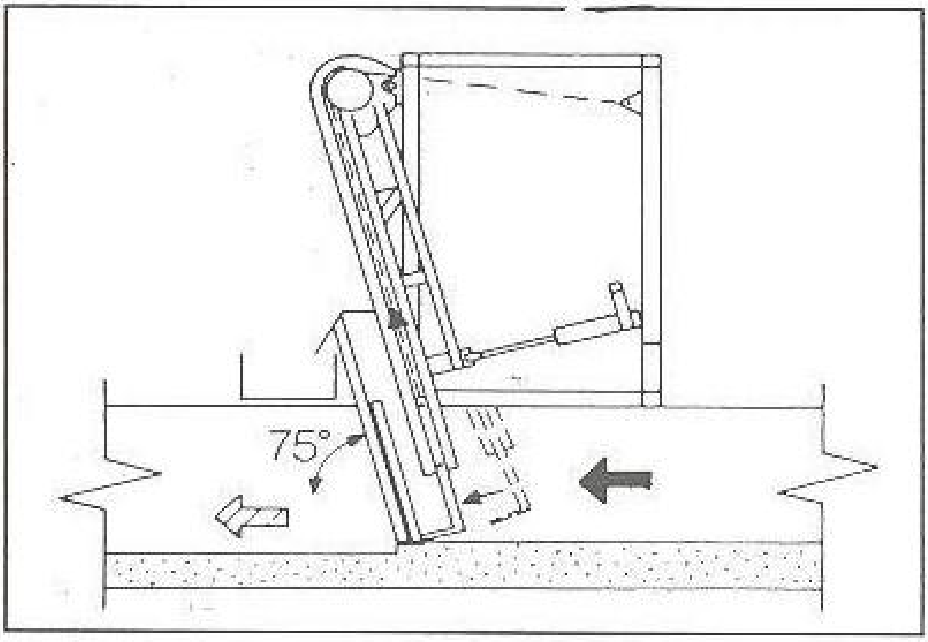
Appendixes

Appendix (1): Types of Mechanical Screens

Appendix (2): Test of Metal Structure Welding

Appendix (3): Comparison tables of Aerators

Appendix (1): Types of Mechanical Screens



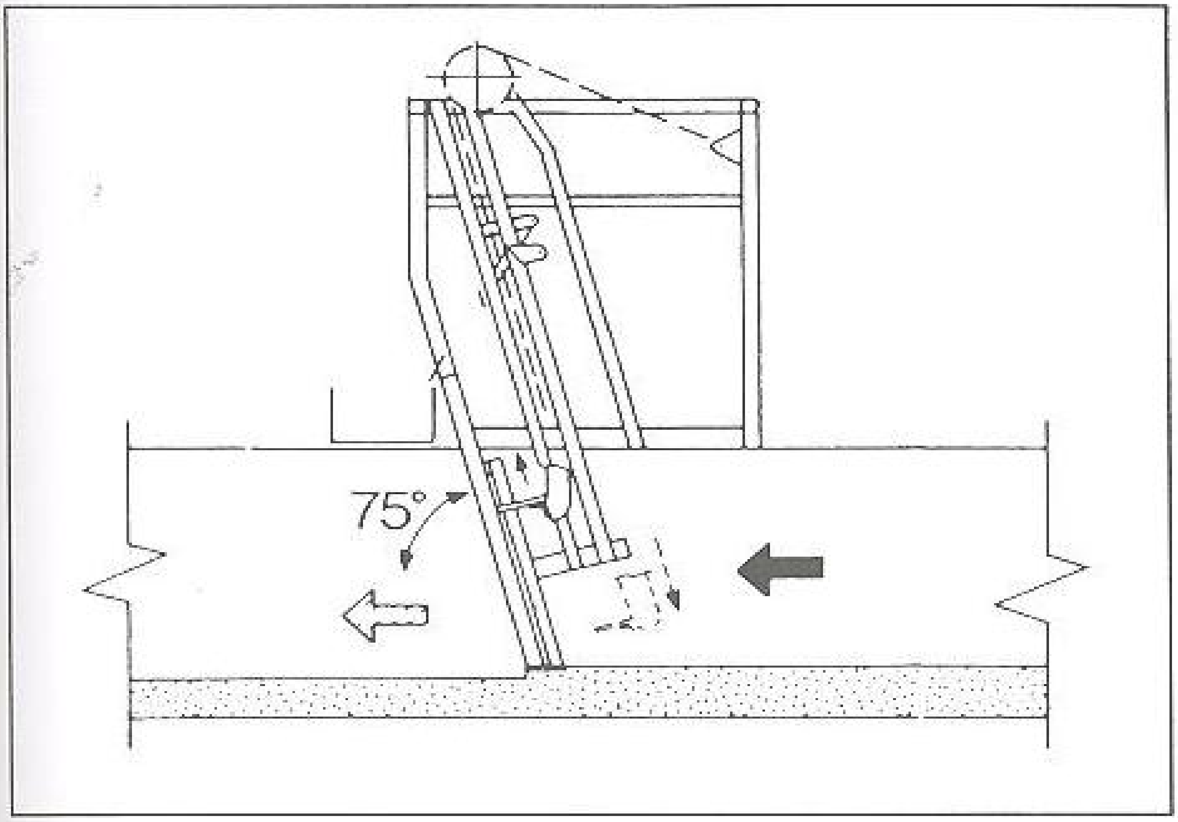
GRAB TYPE SCREEN WITH POWERED ENGAGEMENT.

This screen is of similar design to the Hi-lift screen type RM but incorporates a pivoting raking mechanism powered by an electro mechanical actuator. The rake descends with the actuator ram retracted and the rake held clear of the grid. When the rake reaches the bottom of its travel, the actuator forces it into mesh with the grid and the rake then ascends. If a blockage is encountered, a current sensing device mounted in the control panel will sense the current surge and give a signal to retract the actuator ram. When the current drops, the actuator ram will extend and re-engage the rake with the grid, giving a profiling action around the obstruction.

The drive unit is protected by a second current sensor to disconnect the drive in the event of a major obstruction.

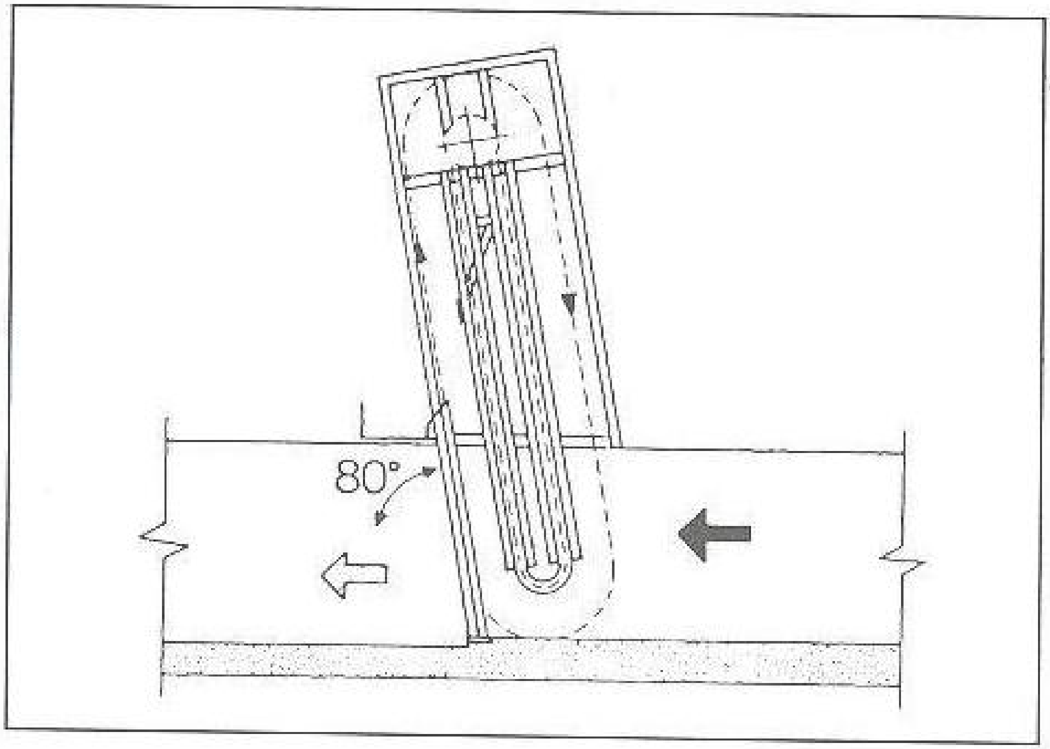
.Control equipment incorporating a P.L.C to ensure the correct operating sequence is recommended, and can be mounted on the screen headframe if required.

Preferred bar spacings are 12mm and 18mm. Other spaces can be accommodated to suit particular requirements.



GRAB TYPE SCREEN FOR MEDIUM TO DEEP CHANNELS.

A reciprocating grab type screen suitable for light solids loading. The straight bar screen is normally inclined at 75^0 to the horizontal and the rake is positively driven on both its downward travel, where it is held clear of the screen grid, and on the upward travel, where the rake tines engage with the grid bars.
Drive is by a single direct coupled motor, and the motor reversing switches, which include the park out of flow switch are readily accessible.
The screen drive is protected by a torque limiting coupling fitted with a limit switch.
Preferred bar spacings are 12mm and 18mm . Other spaces can be accommodated to suit particular requirements.



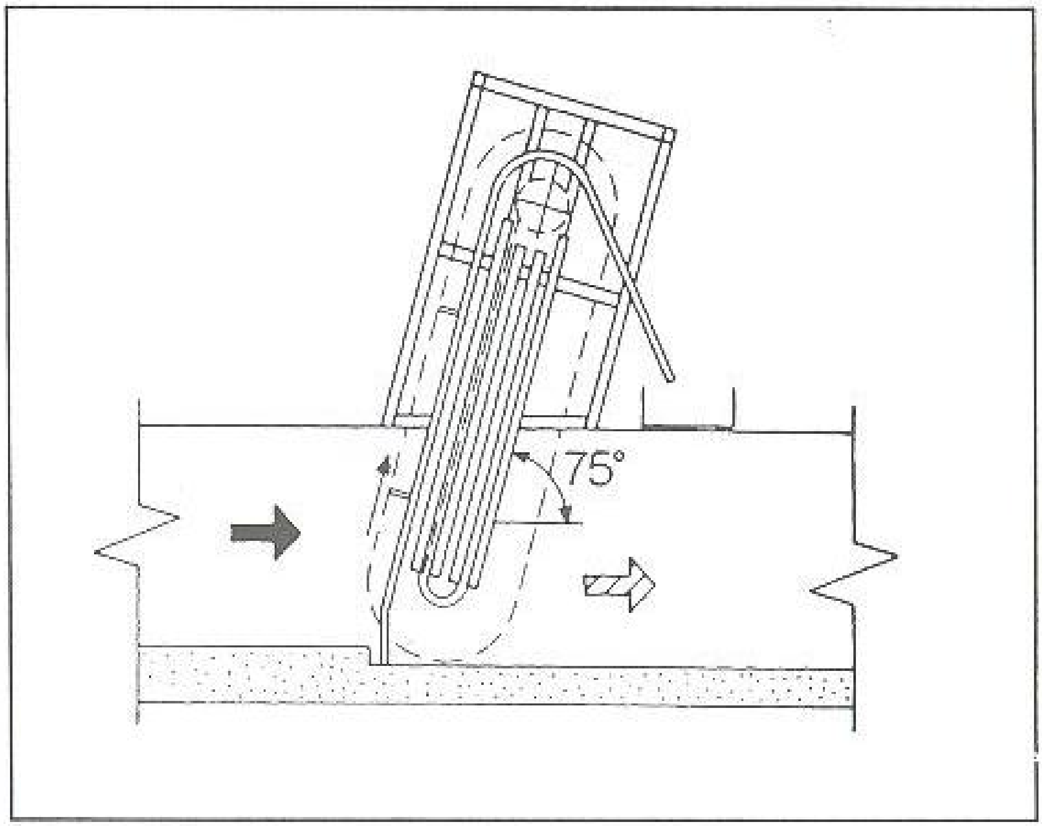
FOR MEDIUM TO DEEP CHANNELS AND HEAVY SOLIDS LOADING.

An inclined bar screen particularly suitable for applications where the flow is of high solids/liquid ratio. The screen requires only a short lenght of parallel channel. The grid is raked by robust tines, the number of sets of tines can be varied to give very rapid removal of screenings.

Screenings are carried up the inclined screen grid/deadplate to the discharge point. The raking action is on the endless chain principle, although there are no bearings or bottom sprockets in the flow.

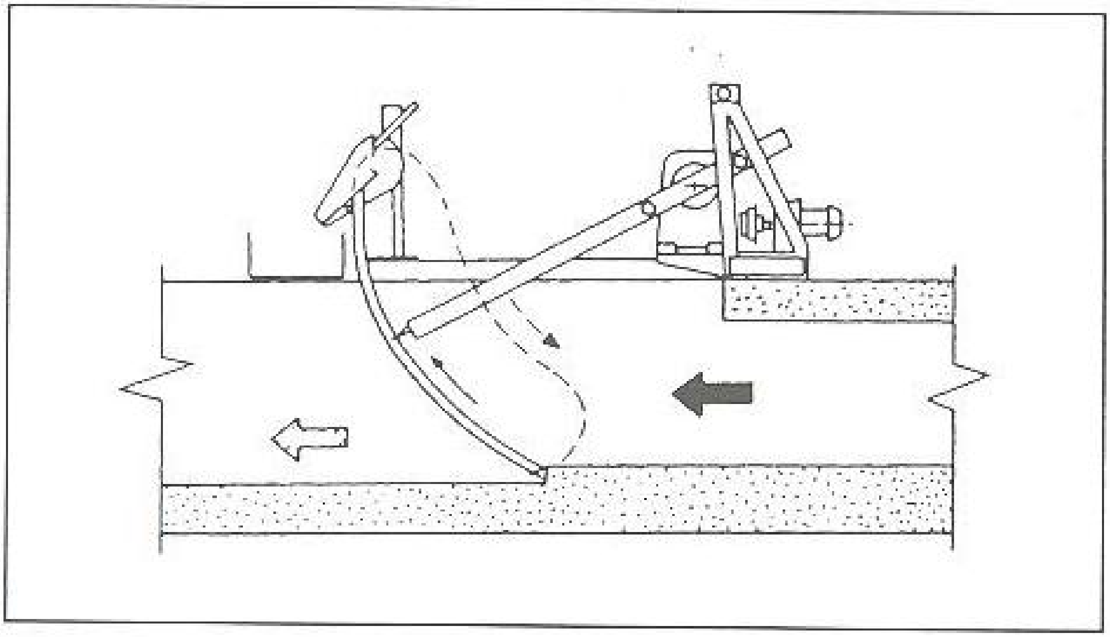
The screen drive is shaft mounted and is protected by a current sensor.

Preferred bar spacings are 6mm, 12mm and 18mm. Other spaces can be accommodated to suit particular requirements.



COARSE SCREEN FOR LARGE SOLIDS

A multi back raked coarse screen of very robust construction.
The raking mechanism is mounted downstream of the screen grid and is protected by the grid which is usually inclined at 80^0 to the horizontal. Screenings are carried over the top curved section and delivered to the downstream side by rake tines which protrude through the grid. The number of rake tines can be varied to suit the solids loading and the tines are removable in sections should replacement become necessary.
The screen drive unit is shaft mounted and is protected by a current sensor.
Preferred bar spacings are 24mm upwards



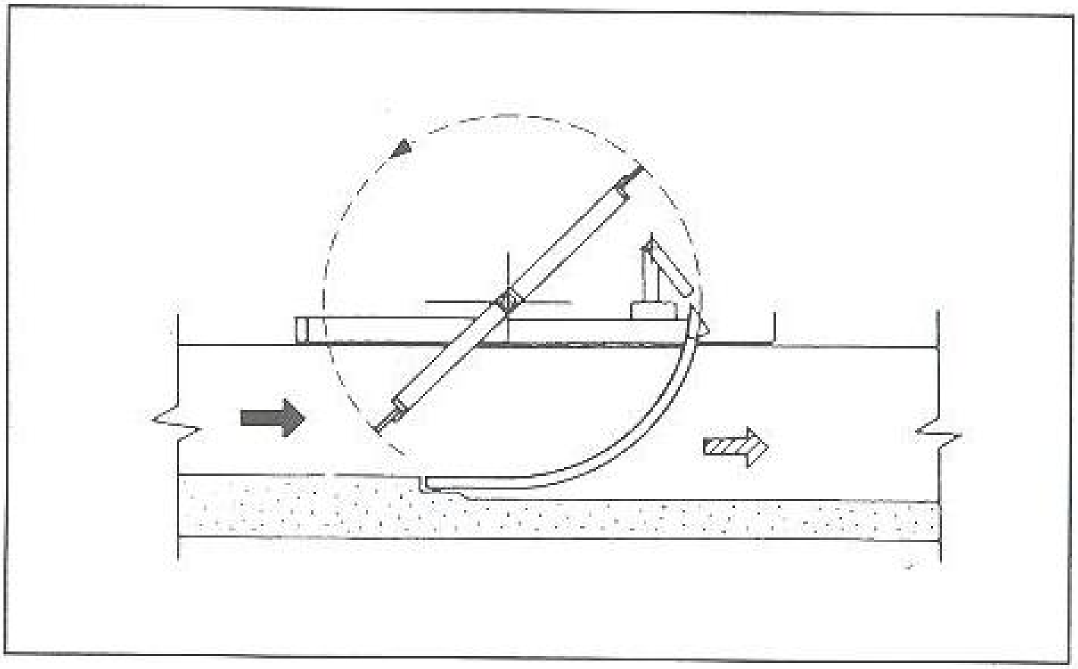
FOR SHALLOW TO MEDIUM DEPTH CHANNELS USUALLY UP TO 2600MM.

A robust mechanically raked curved bar screen which gives a large effective screening area. The raking mechanism requires the minimum of maintenance and all moving parts, with the exception of the rake arm, are above coping level.

The rotary motion of the drive is converted by a simple crank and link arrangement into a profile action which clears the grid on the upward stroke, disengages, and returns to the foot of the grid when the cycle is repeated. Screenings are discharged by a pivoting scraper down a stainless steel hinged apron.

The screen drive is protected by a torque limiting coupling in addition to normal starter overloads. The rake arm parks out of the flow at the end of a running cycle.

Preferred bar spacings are 12mm and 18mm. Other spaces can be accommodated to suit particular requirements.



FOR SHALLOW CHANNELS NORMALLY UP TO 1000MM DEEP.

A fully curved rotary screen of rugged construction giving the maximum screening area for a given width of channel.

Two sets of rake tines rotating through 360^0 ensure rapid removal of solids, which are lifted up to a pivoted scraper and are discharged down an apron.

The screen drive is directly coupled and is protected by either current sensor or torque limiting coupling. The rake arms always park out of the flow at the end of a running cycle.

Preferred bar spacings are 12mm and 18mm . Other spaces can be accommodated to suit particular requirements.

Appendix (2): Test of Metal Structure Welding

APPENDIX 9 - MANDATORY NONDESTRUCTIVE EXAMINATION

ARTICLE 9-1 MAGNETIC PARTICLE EXAMINATION

9-100 SCOPE

(a) This Appendix provides procedures which shall be followed whenever magnetic particle examination is specified in this Division.

(b) Article 7 of Section V shall be applied for the detail requirements in methods and procedures, and the additional requirements specified within this Appendix.

(c) Magnetic particle examination shall be performed in accordance with a written procedure certified by the Manufacturer to be in accordance with the requirements of T-150 of Section V.

9-110 CERTIFICATION OF COMPETENCE OF NONDESTRUCTIVE EXAMINER

Personnel conducting the magnetic particle examination shall be qualified in accordance with AI-311.

9-120 EVALUATION OF INDICATIONS

Indications will be revealed by retention of magnetic particles. All such indications are not necessarily imperfections, however, since excessive surface roughness,magnetic permeability variations (such as at the edge of heat affected zones), etc, may produce similar indications.

An indication is the evidence of a mechanical imperfection. Only indications which have any dimension greater than 1/16 in. shall be considered relevant.

(b) A rounded indication is one of circular or elliptical shape with a length equal to or less than three times its width.

9-130 ACCEPTANCE STANDARDS

These acceptance standards shall apply unless other more restrictive standards are specified for specific materials or applications within this Division.

All surfaces to be examined shall be free of:

(a) relevant linear indications;

(b) relevant rounded indications greater than 3/16 in.;

(c) four or more relevant rounded indications in a line separated by 1/16 in. or less, edge-to-edge.

9-140 REPAIR REQUIREMENTS

Unacceptable imperfections shall be removed and reexamination made to assure complete removal. Whenever an imperfection in removed by chipping or grinding and subsequent repair by welding is not required, the excavated area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners. Where welding is required after removal of an imperfection, the area shall be cleanded and welding performed in accordance with a qualified welding procedure.

9-140.1 Treatment of Indications Believed Nonrelevant. Any indication which is believed to be Nonrelevant shall be regarded as an imperfection unless it is shown by reexamination by the same method or by the use of other nondestructive methods and/or by surface conditioning that no unacceptable imperfection is present.

9-140.2 Examination of Areas From Which Imperfections Have Been Removed. After an imperfection is though to have been removed and prior to making weld repairs, the area shall be examined by suitable methods to assure the imperfection has been eliminated.

9-140.3 Reexamination of Repair Areas. After repairs have been made, the repaired area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners, and reexamined by the magnetic particle method and by all other methods of examination that were originally required for the affected area, except that, when the depth of repair is less than the radiographic sensitivity required, reradiography may be omitted.

ARTICLE 7
MAGNETIC PARTICLE EXAMINATION

T-700 INTRODUCTION

The magnetic particle examination method may be applied to detect cracks and other discontinuities on or near the surfaces of ferromagnetic materials. The sensitivity is greatest for surface discontinuities and diminishes rapidly with increasing depth of subsurface discontinuities below the surface. Typical types of discontinuities that can be detected by this method are cracks, laps, seams, cold shuts, and laminations.

In principle, this method involves magnetizing an area to be examined, and applying ferromagnetic particles (the examinations medium) to the surface. The particles will form patterns on the surface where cracks and other discontinuities cause distortions in the normal magnetic field. These patterns are usually characteristic of the type of discontinuity that is detected.

Whichever technique is used to produce the magnetic flux in the part, maximum sensitivity will be to linear discontinuities oriented perpendicular to the lines of flux. For optimum effectiveness in detecting all types of discontinuities, each area should be examined at least twice, with the lines of flux during one examination approximately perpendicular to the lines of flux during the other.

T-710 SCOPE

When specified by the referencing Code Section, the magnetic particle examination techniques described in this Article shall be used. In general, this Article is in conformance with SE-709, Standard Recommended Practice for Magnetic Particle Examination. This document provides additional details to be considered in the procedures used.

When this Article is specified by a referencing Code Section, the magnetic particle method described in this Article shall be used together with Article 1, General Requirements. Definition of terms used in this Article may be found in Appendix (A) Glossary of Terms Used in Nondestructive Examination, or SE-269.

7-740 GENERAL REQUIREMENTS
T-721 Procedure

Examination procedures shall be based on the following information:

(a) the materials, shapes, or sizes to be examined, and the extent of the examination;

(b) magnetization techniques to be used;

(c) equipment to be used for magnetizaton;

(d) surface preparation (finishing and cleaning);

(e) type of ferromagnetic particles to be used: manufacturer, color, wet or dry, etc;

(f) magnetization currents (type and ampersge);

(g) demagnetization.

T-722 Method of Examination

Examination shall be done by the continuous method; that is, the magnetizing current remains on while the examination medium is being applied and while excess of the examination medium is being removed.

T-723 Techniques and Materials

The ferromagnetic particles used as an examination medium shall be either wet or dry, and may be either fluorescent or nonfluorescent.

One or more of the following five magnetization techniques shall be used:

(a) prod technique;

(b) longitudinal magnetization technique;

(c) circular magnetization technique;

(d) yoke technique;

(e) multidirectional magnetization technique.

T-724 Surface Preparation

(a) Satisfactory results are usually obtained when the surfaces are in the as-welded, as-rolled, as-cast, or as-forged conditions. However, surface preparation by grinding or machining may be necessary where surface irregularities could mask indications due to discontinuities.

(b) Prior to magnetic particle examination, the surface to be examined and all adjacent areas within at least, 1 in. Shall be dry and free of all dirt, grease, lint, scale, welding flux and spatter, oil, or other extraneous matter that could interfere with the examination.

(c) Cleaning may be accomplished using detergents, organic solvents, descaling solutions, paint removers, vapor degreasing, sand or grit blasting, or ultrasonic cleaning methods.

(d) If coatings are left on the part in the area being examined, it must be demonstrated that indications can be detected through the maximum coating thickness applied.

NOTE: Refer to T-100 for guidance for demonstration of the special procedure/technique.

T-725 Magnetization

A suitable and appropriate means for producing the necessary magnetic flux in the part shall be employed using one or more of the techniques listed in T-722 and described in T-740 .

T-726 Examination Medium

The finely divided ferromagnetic particles used for the examination shall meet the following requirement.

(a) Dry Particles, If dry particles are used , the color of the particles (dry powder) shall provide adequate contrast with the surface being examined. Additional specific requirements on the use of dry particles are given in SE-709, Standard Recommended Practice for Magnetic Particle Examination. Magnetic particles examination shall not be performed if the surface temperature of the part exceeds 600^0F.

(b) Wet Particles. If wet particles are used, the color of the particles shall provide adequate contrast with the surface being examined. The particles shall be suspended in a suitable liquid medium in the concentration recommended in SE-709, Standard Recommended Practice for Magnetic Particle Examination, which contains additional specific requirements on the use of wet particles. The temperature of the wet particle suspension and the surface of the part shall not exceed 135^0 F.

(c) Fluorescent Particles. With fluorescent particles the examination is performed using an ultraviolet light, called black light. The examination shall be performed as follows.

(1) It shall be performed in a darkened area.

(2) The examiner shall be in the darkened area for at least 5 min prior to performing the examination to enable his eyes to adapt to dark viewing . If the examiner wears glasses or lenses, they shall not be photosensitive.

(3) The black light shall be allowed to warm up for a minimum of 5 min prior to use or measurement of the intensity of the ultraviolet ligh emitted.

(4) The black light intensity shall be measured with a black light meter. A minimum of 800 µW/cm2 on the surface of the part being examined shall be required. The black light intensity shall be measured at least once every 8 hr, and whenever the work station is changed.

T-727 Magnetizing Field Adequacy and Direction

T-727.1 When it is necessary to verify the adequacy or direction of the magnetizing field, the magnetic particle field indicator described in Fig. T.727 shall be used by positioning the indicator on the surface to be examined.

When using this indicator, a suitable flux or field strength is indicated when a clearly defined line of magnetic particles forms across the copper face of the indicator when the magnetic particles are applied simultaneously with the magnetizing force.

When a clearly defined line of particles is not formed, or is not formed in the desired direction, the magnetizing technique shall be changed or adjusted.

T-727.2 The magnetic particle field indicator is only permitted for determining field adequacy when specifically referenced by the magnetizing technique in T-744.2(c), T-744.2(d), T-747.2 T-245.1(b) (b), T-245.1(b) (6), T-745.2(a), and T-745.2(b).

T-728 Rectified Current

(a) Whenever direct current is required rectified current may be used. The rectified current for magnetization shall be either three-phase (full-wave rectified) current, or single phase (half-wave rectified) current.

(b) The amperage required with three-phase, full-wave rectified current shall be verified by measuring the average current.

(c) The amperage required with single-phase (half-wave rectified) current shall be verified by measuring

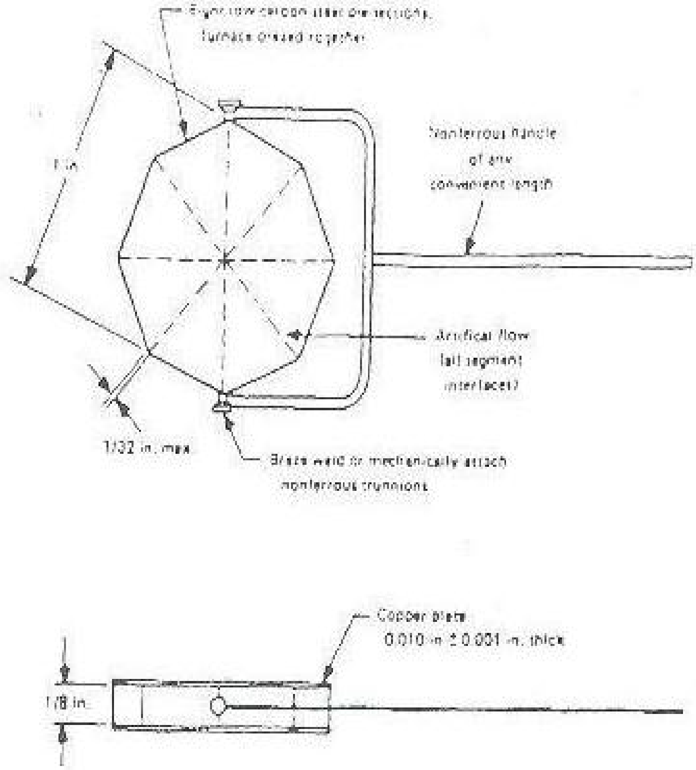


FIG T-727 MAGNETIC PARTICLE FIELD INDICATOR

the average current output during the conducting half cycle only.

T-729 Demagnetization

When residual magnetism in the part could interfere with subsequent processing or usage, the part shall be demagnetized any time after completion of the examination.

T-730 CALIBRATION OF EQUIPMENT

T-731 Frequency of Calibration

(a) Frequency. Each piece of magnetizing equipment with an ammeter shall be calibrated at least once a year, or whenever the equipment has been subjected to major electric repair, periodic overhaul, or damage. If equipment has not been in use for a year or more, calibration shall be done prior to first use.

(b) Procedure. The accuracy of the unit's meter shall be verified annually by equipment traceable to a national standard. Comparative readings shall be taken for at least three different current output levels encompassing the usable range.

(c) Tolerance. The unit's meter reading shall not deviate by more than ±10% of full scale, relative to the actual current value as shown by the test meter.

NOTE: When measuring half - wave rectified current with a direct current test meter, readings shall be multiplied by 2.

T-740 EXAMINATION

T- 741 Direction of Magnetization

At least two separate examinations shall be performed on each area. During the second examination, the lines of magnetic flux shall be approximately perpendicular to those used during the first examination.

A different technique for magnetization may be used for the second examination.

T-742 Examination Coverage

All examination shall be conducted with sufficient overlap to assure 100% coverage at the required sensitivity (T-727).

T-743 Prod Technique

T-743.1 Magnetizing Procedure. For the prod technique, magnetization is accomplished by portable prod type electrical contacts pressed against the surface in the area to be examined. To avoid arcing, a remote control switch, which may be built into the prod handles, shall be provided to permit the current to be turned on after the prods have been properly positioned.

T-743.2 Magnetizing Current. Direct or rectified magnetizing current Shall be used. The current shall be 100 (minimum) amp/in. to 125 (maximum) amp/in. of prod spacing for sections 3/4 in. thick, or greater. For sections less than 3/4 in. thick, the current shall be 90 amp/in. to 110 amp/in. of prod spacing.

T-743.3 Prod Spacing. Prod spacing shall not exceed 8 in. Shorter spacing may be used to accommodate the geometric limitations of the area being examined or to increase the sensitivity, but prod spacings of less than 3 in. are usually not practical due to banding of the particles around the prods. The prod tips shall be kept clean and dressed. If the open circuit voltage of the magnetizing curent source is greater than 25 V, lead, steel, or aluminum (rather than copper) tipped prods are recommended to avoid copper deposites on the part being examined.

T-744 Longitudinal Magnetization Technique

T-744.1 Magnetizing Procedure. For this technique, magnetization is accomplished by passing current through a multi-turn fixed coil (or cables) that is wrapped around the part or section of the part to be examined. This produces a longitudinal magnetic field parallel to the axis of the coil.

If a fixed, prewound coil is used the part shall be placed near the side of the coil during inspection. This is of special importance when the coil opening is more than 10 times the corss-sectional area of the part.

T-744.2 Magnetic Field Strength. Direct or rectified current shall be used to magnetize parts examined by this technique. The required field strength shall be calculated based on the length L and the diameter D of the part in accordance with (a), (b), or as established in (c), below. Long parts shall be examined in sections not to exceed 18 in, and 18 in. shall be used for the part L in calculating the required field strength. For noncylindrical parts, D shall be the maximum cross-sectional diagonal.

(a) Parts With L/D' Ratios Equal to or Greater Than 4. The magnetizing current shall be within $\pm$ 10% of the ampere-turns value determined as follows:

$$\text{Ampere-turns} = \frac{35{,}000}{(L/D) + 2}$$

For example, a part 10 in. long x 2 in. diameter has an L/D ratio of 5. Therefore

$$\frac{35{,}000}{(5 + 2)} = 5000 \text{ ampere-turns}$$

(b) Parts With L/D Ratios Less Than 4 but Not Less Than 2. The magnetizing ampere-turns shall be within $\pm$ 10% of the ampere-turns' value determined as follows:

$$\text{Ampere-turns} = \frac{45{,}000}{(L/D)}$$

(c) If the area to be magnetized extends beyond 6 in. on either side of the coils, field adequacy shall be demonstrated using the magnetic field indicator per T-727.

(d) For large parts due to size and shape, the magnetizing current shall be 1200 ampere-turns to 4500 ampere turns. The field adequacy shall be demonstrated using the magnetic field indicator per T-727.

T-744.3 Magnetizing Current. The current required to obtain the necessary magnetizing field strength shall be determined by dividing the ampere-turns obtained in steps (a) or (b) above by the number of turns in the coil as follows:

$$\text{Ampere (meter reading)} = \frac{\text{ampere-turns}}{\text{turns}}$$

For example, if a 5-turn coil is used and the ampere-turns required are 5000, use

$$\frac{5000}{5} = 1000 \text{ amperes} \pm (10\%)$$

T-754 Circular Magnetization Technique

T-754.1 Direct Contact Technique

(a) Magnetizing Procedure. For this technique, magnetization is accomplished by passing current through the part to be examined. This produces a circular magnetic field that is approximately perpendicular to the direction of current flow in the part.

(b) Magnetizing Current. Direct or rectified (half-wave rectified or full-wave rectified) magnetizing current shall be used. The required current shall be determined using the following guidelines:

(1) for parts with outer diameteres up to 5 in. 700 amp/in. to 900 amp/in. of diameter shall be used.

(2) for parts with outer diameters over 5 in. up to 10 in. - 500 amp/in. to 700 amp/in. of diameter shall be used;

(3) for parts with outer diameters over 10 in., up to 15 in. - 300 amp/in. to 500 amp/in. of diameter shall be used;

(4) for parts with outer diameters over 15 in. - 100 amp/in. to 330 amp/in. of outer diameters shall be used;

(5) for parts with geometric shapes other than round, the greastest cross-sectional diagonal in a plane at right angles to the current flow shall determine the inches to be used in the above computations.

(6) If the current levels required for (b) (3) and (4) above cannot be obtained, the maximum current obtainable shall be used and the field adequacy shall be demonstrated by using the magnetic particle field indicator per T-727. For noncylindrical parts and when examining large parts by clamping contacts to the wall thickness, field adequacy shall be demonstrated by using the magnetic particle field indicator per T-727.

T-745.2 Central Conductor Technique

(a) Magnetizing Procedure. For this technique, a central conductor is used to examine the internal surfaces of ring or cylindrically shaped parts. The central conductor technique may also be used for examining the outside surfaces of these shapes. Where large diameter cylinders are to be examined, the conductor shall be positioned close to the internal surface of the cylinder. When the conductor is not centered, the circumference of the cylinder shall be examined in increments and a magnetic particle field indicator, applied in accordance with T-727, shall be used to determine the extent of the arc that may be examined for each conductor position. Bars, or cables passed through the bore of a cylinder, may be used to induce circular magnetization.

(b) Magnetizing Current. The field strength required shall be equal to that determined in T-745.1 (b) for a single-turn central conductor. The magnetic field will increase in proportion to the number of times the central conductor cable passes through a hollow part. For example, if 6000 amp are required to examine a part using a single central conductor, 3000 amp are required when 2 turns of the through cable are used; and 1200 amp are required if 5 turns are used. When the central conductor technique is used, magnetic field adequacy shall be verified using a magnetic particle field indicated in accordance with T-727 (see Fig. T-745.2).

T-746 Yoke Technique

T-746.1 Application. This method shall only be applied to detect discontinuities that are open to the surface of the part.

T-746.2 Magnetizing Procedure. For this technique alternating or direct current electromagnetic yokes, or permanent magnet yokes, shall be used.

NOTE: Except for materials 1/4 in. or less in thickness, alternating current yokes are superior to direct or permanent magnet yokes of equal lifting power for the detection of surface discontinuities.

T-746.3 Lifting Power of Yokes

(a) The magnetizing force of yokes shall be checked at least once a year, or whenever a yoke has been damaged. If a yoke has not been in use for a year or more, a check shall be done prior to first use.

(b) Each alternating current electromagnetic yoke shall have a lifting power of at least 10 lb at the maximum pole spacing that will be used.

(c) Each direct current or permanent magnetic yoke shall have a lifting power of at least 40 lb at the maximum pole spacing that will be used.

(d) each weight shall be weighed with a scale from a reputable manufacturer and stenciled with the applicable nominal weight prior to first use. A weight need only be verified again if damaged in a manner that could have caused potential loss of material.

T-747 Multidirectional Magnetization Technique

T-747.1 Magnetizing Procedure. For this technique magnetization is accomplished by high amperage power packs operating as many as three circuits that are energizd one at a time in rapid succession. The effect of these rapidly alternating magnetizing currents is to produce an overall magnetization of the part in multiple directions. Circular or longitudinal magnetic fields may be generated in any combination using the various techniques described in T-744 and T-745.

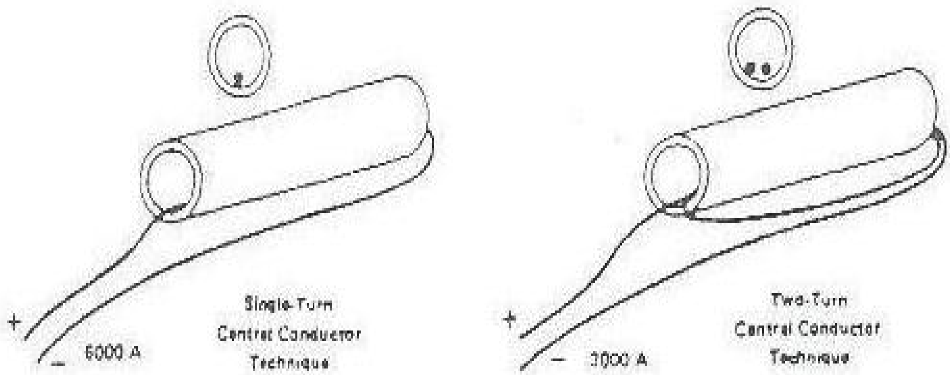


FIG. T-745.2 SIGNALE -TURN AND TWO TURN CENTRAL CONDUCTOR TECHNIQUE

T-747.2 Magnetic Field Strength. Only three phase, full-wave rectified current shall be used to magnetize the part. The initial magnetizing current requirements for each circuit shall be established using the previously described guidelines (see T-744 and T-745). The adequacy of the magnetic field shall be demonstrated in accordance with T-727, and a magnetic particle field indicator shall be used to verify that an adequate field is obtained in at least two nearly perpendicular directions. For areas where adequate field strengths cannot be demonstrated, additional magnetic particle techniques shall be used to obtain the required two directional coverage.

T-750 Evaluation

(a) All indications shall be evaluated in terms of the acceptance standards of the referencing Code Section.

(b) Discontinuities on or near the surface are indicted by retention of the examination medium. However. Localized surface irregularities due to machining marks or other surface conditions may produce false indication.

(c) Broad areas of particle accumulation which migh mask indications from discontinuities are prohibited, and such areas shall be cleaned and reexamined.

T-760 Reports

T-761 Multidirectional Magnetization Technique Sketch

A technique sketch shall be prepared for each different geometry examined, showing the part geometry, cable arrangement and connections, magnetizing current for each circuit, and the areas of examination where adequate field strengths are obtained. Parts with repetitive geometries, but different dimensions, may be examined using a single sketch provided that the magnetic field strength is adequate when demonstrated in accordance with T-747.2.

ARTICLE 9-2
LIQUID PENETRANT EXAMINATION

9-200 SCOPE

(a) This Article describes methods which shall be employed whenever liquid penetrant examination is specified in this Division.

(b) Article 6 of Section V shall be applied for detail requirements in methods, procedures and qualifications, unless specified within this Article.

(c) Liquid penetrant examination shall be performed in accordance with a written procedure certified by the Manufacturer to be in accordance with the requirements of T-150 of Section V.

9-210 CERTIFICATION OF COMPETENCE OF NONDESTRUCTIVE EXAMINER

Personnel conducting the liquid penetrant examination shall be qualified in accordance with AI-311.

9-220 EVALUATION OF INDICATIONS

An indication is the evidence of a mechanical imperfection. Only indications with major dimensions greater than 1/16 in. shall be considered relevant.

(a) A linear indication is one having a length greater than three times the width.

(b) A rounded indication is one of circular or elliptical shape with the length equal to or less than three times the width.

(c) Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

9-230 ACCEPTANCE STANDARDS

These acceptance standards shall apply unless other more restrictive standards are specified for specific materials or applications within this Division.

All surfaces to be examined shall be free of:

(a) relevant linear indications;

(b) relevant rounded indications greater than 1/16 in.;

(c) four or more relevant rounded indications in a line separated by 1/16 in. or less (edge-to-edge).

9-240 REPAIR REQUIREMENTS

Unacceptable imperfections shall be removed and reexamination made to assure complete removal. Whenever an imperfection is removed by chipping or grinding and subsequent repair by welding is not required, the excavated area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners. Where welding is required after removal of an imperfection, the area shall be cleaned and welding performed in accordance with a qualified welding procedure.

9-240.1 Treatment of Indications Believed Nonrelevant. Any indication which is believed to be nonrelevant shall be regarded as an imperfection unless it is shown by reexamination by the same method or by the use of other nondestructive methods and/or by surface conditioning that no unacceptable imperfection is present.

9-240.2 Examination of Areas From Which Imperfections Have Been Removed. After an imperfection is thought to have been removed and prior to making weld repairs, the area shall be examined by suitable methods to assure the imperfection has been eliminated.

9-240.3 Reexamination of Repair Areas. After repairs have been made, the repaired area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners and reexamined by the liquid penetrant method and by all other methods of examination that were originally required for the affected area, except that, when the depth of repair is less than the radiographic sensitivity required, reradiography may be omitted.

ARTICLE 6
LIQUID PENETRANT EXAMINATION

T-600 INTRODUCTION

The liquid penetrant examination method is an effective means for detecting discontinuities which are open to the surface of nonporous metals and other materials. Typical discontinuities detectable by this method are cracks, seams, laps, cold shuts, laminations, and porosity.

In principle, a liquid penetrant is applied to the surface to be examined and allowed to enter discontinuities. All excess penetrant is then removed, the part is dried, and a developer is applied. The developer functions both as a blotter to absorb penetrant that has been trapped in discontinuities, and as a contrasting background to enhance the visibility of penetrant indications. The dyes in penetrants are either color contrast (visible under white light) or fluorescent (visible under ultraviolet light).

A 80 T-610 SCOPE

When specified by the referencing Code Section, the liquid penetrant examination techniques described in this Article shall be used. The following listed SE Standards provide details which may be considered in the specific procedures used:

(a) SE-165, Standard Practice for liquid Penetrant Inspection Method.

(b) es-1209, Standard Test Method for Fluorescent Penetrant examination Using the Water Washable Process.

(c) SE-1219, Standard Test Method for Fluorescent Penetrant Examination Using the Solvent removable Process.

(d) SE-1220, Standard Test Method for Visible penetrant Examination Using the Solvent Removable Process.

When this Article is specified by a referencing Code Section, the liquid penetrant method described in this Article shall be used together with Article 1, General Requirements. Definitions of terms used in this Article may be found in Appendix A. Glossary of Terms Used in Nondestructive Examination, or in SE-270.

T-620 GENERAL REQUIREMENTS

T-621 Procedure

T-621.1 Initial Procedure. Liquid penetrant examination shall be performed in accordance with a procedure. Such a procedure shall consider at least the following information:

(a) the materials, shapes, or sizes to be examimed. and the extent of the examination;

(b) type (number or letter designation if available) of each penetrant, penetrant remover, emulsifier, and developer;

(c) processing details for pre-examination cleaning and drying, including the cleaning material used and minimum time allowed for drying;

(d) processing details for applying the penetrant; the length of time that the penetrant will remain on the surface (dwell time), and the temperature of the surface and penetrant during the examination if outside 60^{0}F to 125^{0}F range;

(e) processing details for removing excess penetrant from the surface, and for drying the surface before applying the developer;

(f) processing details for applying the developer, and length of developing time before interpretation;

(g) processing details for post-examination cleaning.

T-621.2 Procedure Revision. A revised procedure may be required:

(a) whenever a change or substitution is made in the type or family group of penetrant materials (including developers, emulsifiers, etc.) or in the processing techniques:

(b) whenever a change or substitution is made in the type of precleaning materials or processes;

(c) for any change in part processing that can close surface openings of discontinuities or leave interfering deposits, such as the use of grit blast cleaning or acid treatments.

A 90 **T-622 Techniques**

Either a color contrast (visible) penetrant or a flourescent penetrant shall be used with one of the following three penetrant processes:

(a) water washable

(b) post-emulsifying

(c) solvent removable

The visible and fluorescent penetrants used in combination with these three penetrant processes result in six liquid penetrant techniques.

T-623 Penetrant materials

The term penetrant materials, as used in this Article, is intended to include all penetrants, solvents or cleaning agents, developers, etc, used in the examination process.

A 90 **T-624 Technique Restrictions**

Flourescent penetrant examination shall not follow a color contrast penetrant examination. Intermixing of penetrant materials from different families or different manufactures is not permitted. A retest with water washable penetrants may cause loss of marginal indications due to contamination.

T-625 Control of Contaminants

The user of this Article shall obtain certification of contaminant content for all liquid penetrant materials used on nickel base alloys, austenitic stainless steels, and titanium. These certifications shall include the penetrant manufactures batch numbers and the test results obtained in accordance with (a) and (b) below. These records shall be maintained as required by the referencing Code Section.

(a) When examining nickel base alloys, all materials shall be analyzed individually for sulphur content as follows.

(1) An individual sample of the penetrant materials with exception of cleaners shall be prepared for analysis by heating 50 g of the material in a 150 mm nominal diameter glass Petri dish at a temperature of 194^0F to 212^0F for 60 min.

RECAUTION: Provide adequate ventilation to dissipate the emitted vapor.

(2) Analysis of the residue shall be as follows: If the residue is less than 0.0025 g, the material is acceptable without further analysis. If the residue is 0.0025 g or more, the procedure shown in (a) (1) above shall be repeated and the residue analyzed in accordance with ASTM D 129 or ASTM D 1552. Alternately, the material may be decomposed in accordance with ASTM D 516 Method B. The sulphur content shall not exceed 1% of the residue by weight.

(3) An individual sample of cleaner/remover material shall be prepared for analysis by heating 100 g of the material in a 150 mm nominal diameter glass Petri dish at a temperature of 194^0F to 212^0F for 60 min.

PRECAUTION: Provide adequate ventilation to dissipate the emitted vapor.

(4) Analysis of the residue shall be as follows : If the residue is less than

0.005 g, the material is acceptable without further analysis. If the residue is 0.005 g or more, the procedure shown in (a) (3) above shall be repeated and the residue analyzed in accordance with ASTM D 129 or ASTM D 1552. Alternately, the material may be decomposed in accordance with D 129 and analyzed in accordance with ASTM D 516 Method B. The sulphur content shall not exceed 1% of the residue by weight.

(b) When examining austeritic stainless steel or titanium, all materials shall be analyzed individually for chlorine and fluorine content as follows.

(1) An individual sample of the penetrant materials with the exception of cleaners shall be prepared for analysis by heating 50 g of the material in a 150 mm nominal diameter glass Petri dish at a temperature of 194^0F to 212^0F for 60 min.

PRECAUTION: Provide adequate ventilation to dissipate the emitted vapor.

(2) Analysis of the residue shall be as follows: If the residue is less than 0.0025 g, the material is acceptable without further analysis. If the residue is 0.0025 g or more, the procedure shown in (a)(1) above shall be repeated and the residue analyzed in accordance with ASTM D 808 or SE-165 Annex 2 for chlorine and SE-165 Annex 3 for fluorine. The chlorine plus fluorine content shall not exceed 1% of the residue by weight.

(3) An individual sample of the cleaner/remover material shall be prepared for analysis by heating 100 g of the material in a 150 mm nominal diameter glass

Petri dish at a temperature of 194^0F to 212^0F for 60 min.

PRECAUTION: Provide adequate ventilation to dissipate the emitted vapor.

(4) Analysis of the residue shall be as follows: If the residue is less than 0.005 g, the material is acceptable without further analysis. If the residue is 0.005 g or more, the procedure shown in (a)(3) above shall be repeated and the residue analyzed in accordance with ASTM D 808 or SE-165 Annex 2 for chlorine and SE-165 Annex 3 for fluorine. The chlorine plus fluorine content shall not exceed 1% of the residue by weight.

T-626 Surface Preparation

(a) In general, satisfactory results may be obtained when the surface of the part is in the as-welded, as-rolled, as-cast, or as-forged condition. Surface preparation by grinding, machining, or other methods may be necessary where surface irregularities could mask indications of unacceptable discontinuities.

CAUTION: Conditioning of surfaces prior to examination can affect the results. See Article 24, SE-165, Annex 1, for general precautions relative to surface conditioning.

(b) Prior to each liquid penetrant examination, the surface to be examined and all adjacent areas within at least 1 in. shall be dry and free of all dirt, grease, lint, scale, welding flux, weld spatter, paint, oil, and other extraneous matter that could obscure surface openings or otherwise interfere with the examination.

(c) Typical cleaning agents which may be used are detergents, organic solvents, descaling solutions, and paint removers. Degreasing and ultrasonic cleaning methods may also be used.

(d) Cleaning solvents shall meet the requirements of T-625. The cleaning method employed is an important part of the examination process.

T-627 Drying After Preparation

After cleaning, drying of the surfaces to be examined shall be accomplished by normal evaporation or with forced hot or cold air. A minimum period of time shall be established to ensure that the cleaning solution has evaporated prior to application of the penetrant.

T- 640 EXAMINATION

T-614 Techniques for Standard Temperatures

As a standard technique, the temperature of the penetrant and the surface of the part to be processed shall not be below 60^0F nor above 125^0F throughout the examination period. Local heating or cooling is permitted provided the part temperature remains in the range of 60^0F to 125^0F during the examination. Where it is not practical to comply with these temperature limitations, other temperatures and times may be used, provided the procedures are qualified as specified in T- 648.

T-642 Penetrant Application

The penetrant may be applied by any suitable means, such as dipping, brushing, or spraying. If the penetrant is applied by spraying using compressed-air-type apparatus, filters shall be placed on the upstream side near the air inlet to preclude contamination of the penetrant by oil, water, dirt, or sediment that may have collected in the lines.

T-643 Penetration Time

Penetration time is critical. The minimum penetration time shall be as recommended in SE-Standards referenced in T-610 or as qualified by demonstration for specific applications.

T-644 Excess Penetrant Removal

After the specified penetration time has elapsed, any penetrant remaining on the surface shall be removed, taking care to minimize removal of penetrant from discontinuities.

T-644.1 Water washable Penetrants. Excess water washable penetrant shall be removed with a water spray. The water pressure shall not exceed 50 psi, and the water temperature shall not exceed 110^0F.

T-644.2 Post- Emulsifying Penetrants. With post-emulsifying penetrants, the emulsifier shall be applied by spraying or dipping. Emulsification time is critical, and governed by surrface roughness and type of discontinuities sought. It shall not exceed 5 min unless other times have been qualified by actual tests. After emulsification, the mixture shall be removed by a water spray using the same processes as for water washable penetrants.

T-644.3 Solvent removable Penetrants, Excess solvent removable penetrants shall be removed by wiping with a cloth or absorbent paper, repeating the operation until most traces of penetrant have been removed . The remaining traces shall be removed by lightly wiping the surface with cloth or absorbent paper moistened with solvent. To minimize removal of penetrant from discontinuities, care shall be taken to avoid the use of excess solvent. Flushing the surface with solvent, following the application of the penetrant and prior to developing, is Prohibited.

T-645 Drying After Excess penetrant removal

(a) For the water washable or post emulsifying technique, the surfaces may be dried by blotting with clean materials or by using circulating air, provided the temperature of the surface is not raised above 125^0F.

(b) For the solvent removable technique, the surfaces may be dried by normal evaporation, blotting, wiping, or forced air.

T-646 Developing

The developer shall be applied as soon as possible after penetrant removal; the time interval shall not exceed that established in the procedure. Insufficient coating thickness may not draw the penetrant out of discontinuities; conversely, excessive coating thickness may mask indications.

With color contrast penetrants, only a wet developer shall be used. With flourescent penetrants, a wet or dry developer may be used.

T-646.1 Dry Developer Application. Dry developer shall be applied only to a dry surface by a soft brush, hand powder bulb, powder gun, or other means, provided the powder is dusted evenly over the entire surface being examined.

T-646.2 Wet Developer Application . Prior to applying suspension type wet developer to the surface, the developer must be thoroughly agitated to ensure adequate dispersion of suspended particles.

(a) Aqueous Developer Application, Aqueous developer may be applied to either a wet or dry surface. It shall be applied by dipping, brushing, spraying, or other means, provided a thin coating is obtained over the entire surface being examined. Drying time may be decreased by using warm air, provided the surface temperature of the part is not raised above 125^0F. Blotting is not permitted.

(b) Nonaqueous Developer Application. Nonaqueous developer shall be applied only to a dry surface. It shall be applied by spraying, except where safety or restricted access preclude it. Under such conditions, developer may be applied by brushing Drying shall be by normal evaporation.

T-646.3 Developing time for final interpretation begins immediately after the application of a dry developer or as soon as a wet developer coating is dry.

T-647 Interpretation

T-647.1 Final Interpretation. Final interpretation shall be made within 7 to 30 min after the requirements of T-646.3 are satisfied. If bleed-out does not alter the examination results, longer periods are permitted. If the surface to be examined is large enough to preculde complete examination within the prescribed or established time, the examination shall be performed in increments.

T-647.2 Characterizing Indication(s). The type of discontinuities are difficult to evaluate if the penetrant diffuses excessively into the developer. If this condition occurs, close observation of the formation of indications during application of the developer may assist in characterizing and determining the extent of the indications(s).

T-647.3 Color Contrast Penetrants. With a color contrast penetrant, the developer forms a reasonably uniform white coating. Surface discontinuitles are indicated by bleed-out of the penetrant which is normally a deep red color that stains the developer. Indications with a light pink color may indicate excessive cleaning. Inadequate cleaning may leave an excessive background making interpretation difficult. Adequate illumination is required to ensure adequate sensitivity during the examination and evalution of indications.

T- 647.4 Fluorescent Penetrants. With fluorescent penetrants, the process is essentially the same as in T-647.3, with the exception that the examination is performed using an ultraviolet light, called black light. The examination shall be performed as follows.

(a) It shall be performed in a darkened area.

(b) The examiner shall be in the darkened area for at least 5 min prior to performing the examination to enable his eyes to adapt to dark viewing. If the examiner wears glasses or lenses, they shall not be photosensitive.

(c) The black light shall be allowed to warm up for a minimum of 5 min prior to use or measurement of the intensity of the ultraviolet light emitted.

(d) The black light intensity shall be measured with a black light meter. A minimum of 800 w/cm2 on the surface of the part being examined shall be required. The black light intensity shall be measured at least once every 8 hr. and whenever the work station is changed.

A 90 **T-648 Procedure for Nonstandard Temperatures**

A 90 **T- 648.1 General.** When it is not practical to conduct a liquid penetrant examination within the temperature range of 60^0F to 125^0F, the examination procedure at the proposed lower or higher temperature range requires qualification. This shall require the use of a quench cracked aluminum block, which in this Article is designated as a liquid penetrant comparator block.

A 90 **T-648.2 Liquid penetrant Comparator**. The liquid penetrant comparator blocks shall be made of aluminum, ASTM B 209, Type 2024 or SB-211, Type 2024, 3/8 in. thick, and should have approximate face dimensions of 2 in. x 3 in. At the center of each face, an area approximately 1 in. in diameter shall be marked with a 950^0F temperature-indicating crayon or paint. The marked area shall be heated with a blowtorch, a Bunsen burner, or similar device to a temperature between 950F and 975^0F. The specimen shall then be immediately quenched in cold water which produces a network of fine cracks on each face.

The block shall then be dried by heating to approximately 300^0F. After cooling, the block shall be cut in half. One-half of the specimen shall be designated block "A" and the other block "B" for identification in subsequent processing. Figure T-648.2 illustrates the comparator blocks "A" and "B". As an alternate to cutting the block in half to make blocks "A" and "B", separate blocks 2 in x 3 in. can be made using the heating and quenching technique as described above. Two comparator blocks with closely matched crack patterns may be used. The blocks shall be marked "A" and "B".

A 90 **T-648.3 Comparator Application**

(a) If it is desired to qualify a liquid penetrant examination procedure at a temperature of less than 60^0F, the proposed procedure shall be applied to block "B" after the block and all materials have been cooled and held at the proposed examination temperature until the comparison is completed. A standard procedure which has previously been demonstrated as suitable for use shall be applied to block "A" in the 60^0F to 125^0F temperature range. The indications of cracks shall be compared between blocks "A" and "B". If the indications obtained under the proposed conditions on block "B" are essentially the same as obtained on block "A" during examination at 60^0F to 125^0F, the proposed procedure shall be considered qualified for use.

A 90 (b) If the proposed temperature for the examination is above 125^0F, block "B" shall be held at this temperature throughout the examination. The indications of cracks shall be compared as described in T-648.3(a) while block "B" is at the proposed temperature and block "A" is at the 60^0F to 125^0F temperature range.

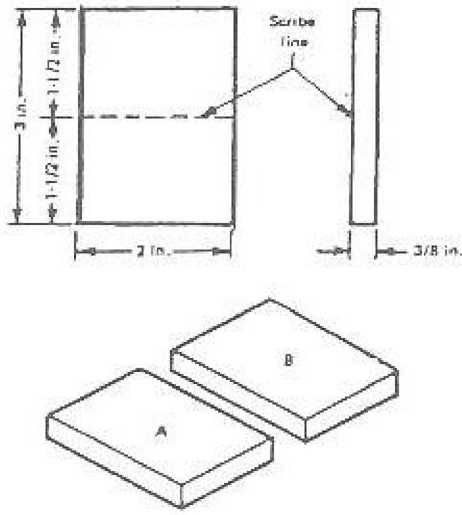


FIG. T-648.2 LIQUIO PENETRANT COMPARATOR

(NOTE : Dimensions given are for guidance only and are not critical.)

(c) A procedure qualified at a temperature lower than 60^0F shall be qualified from that temperature to 60^0F shall be qualified from that temperature to 60^0F.

(d) To qualify a procedure for temperatures above 125^0F, the upper and lower temperature limits shall be established and the procedure qualified at these temperatures.

(e) As an alternate to the requirements of T-648.8.39a) and T-648.3(b) when using color contrast penetrants, it is permissible to use a single comparator block for the standard and nonstandard temperatures and to make the comparison by photography.

(1) When the single comparator block and photographic technique is used, the processing details (as applicable) described in T-648.3(a) and T-648.3(b) apply. The block shall be thoroughly cleaned between the two processing steps. Photographs shall be taken after processing at the nonstandard temperature and then after processing at the standard temperature. The indication of cracks shall be compared between the two photographs. The same criteria for qualification as T-648.3(a) shall apply.

(2) The identical photographic techniques shall be used to make the comparison photographs.

T-650 EVALUATION

(a) All indications shall be evaluated in terms of the acceptance standards of the referencing Code Section.

(b) Discontinuities at the surface will be indicated by bleed-out of penetrant; however, localized surface irregularities due to machining marks or other surface conditions may produce false indications.

(c) Broad areas of fluorescence or pigmentation which could mask indications of discontinuities are unacceptable, and such areas shall be cleaned and reexamined.

Appendix (3): Comparison tables of Aerators

(1) Table for various aerators

Aerator	Features of Equipment	Merit	Demerit	Application
Big bubble type	• Bubbles generated are big	• Low Cost • No cloggings • Low maintenance cost • Easy maintenance • Blower can be installed far away from the aerators (Less pressure loss)	• Low efficiency of O_2 transfer (High cost of power) • Turbulent flow breaks flocs	• Small scale treatment plant (for labour saving)
Fine bubble type	• Bubbles generated are small	• High efficiency of O_2 transfer (Low cost of power) • Easy maintenance	• Air cleaner may be needed to prevent cloggings on the aerators • Turbulent flow breaks flocs	• Large scale treatment plant
Ultrafine bubble type	• Bubbles generated are smaller than that of fine bubble type	• Efficiency of O_2 transfer is much better • No restriction on the shape of tank • Good for flocculation	• Air cleaner may be needed to prevent clogging • Initial cost is a little high	• Treatment plant to reduce energy cost • Better treatment • Treatment plant that requires high nitrification
Vertical shaft agitator type	• There are two types of float type and fixed type • There are turbine type and propeller type	• Low cost • High efficiency of O_2 transfer • Effective mixing	• Maintenance is not easy if numbers of unit are many • Insufficient nitrification • Not suited for cold area • Turbulent flow breaks flocs • Distribution of DO in the tank is not even	• Treat plant that does not require nitrification • Treatment plant located in hot area • Aerating lagoon
Horizontal shaft drive type	• Waves caused by rotation of aerator transfer O_2 (only for shallow tanks) • There are two types of puddle type and rotor type	• High efficiency of O_2 transfer • Low price • Low maintenance cost	• Limitation of tank shape • Not suited for cold area • Insufficient in nitrification • Turbulent flow breaks flocs	• Oxidation ditch
Combination type	• Air is injected from spurjaring and simultaneously agitated by turbine propellers equipped in the water	• Good mixing • Efficiency of O_2 transfer is ordinary • Supply of air is largely adjustable	• Reducer and air compressor are required • High price • High maintenance cost • Turbulent flow breaks flocs	• Treatment plant that requires wide range of air supply • Nitrification tank

(2) Comparison Table of O_2 Transfer in Water

Aerator		O_2 dissolving efficiency in water (%)	Power efficiency when O_2 transferred in water (kgO_2/kwh)	Required Energy (kwh/kgO_2)
BUBBLING TYPE (C	Big bubble type			
	Static aerator	10 - 16	1.4 - 1.9	0.51 - 0.71
	Big bubble double type	10 - 13	1.4 - 1.9	0.62 - 0.71
	Big bubble single type	8 - 10	1.2 - 1.5	0.60 - 0.71
	Fine bubble type			
	Circling type	15 - 26	1.9 - 3.3	0.31 - 0.55 *
	Ultra fine bubbling type total aeration type	20 - 32	3.0 - 4.6	0.22 - 0.33
MECHANICAL AERATION	Low speed surface aeration type		1.5 - 2.2	0.46 - 0.66
	High speed surface aeration type		1.2 - 1.8	0.55 - 1.82
COMBINATION TYPE	Turbine spurjar	14 - 18	1.2 - 1.8	0.55 - 0.82
	Jet aerator	15 - 26	1.6 - 2.3	0.44 - 0.62

* In case of mixed liquid in the aeration tank, it will be doubled.