
GOVERNMENT OF ANDHRA PRADESH
RURAL WATER SUPPLY & SANITATION DEPARTMENT



REFERESHER COURSE
FOR
RWS &S ENGINEERS

**“PLANNING, DESIGN, IMPLEMENTATION AND MAINTENANCE OF
RURAL WATER SUPPLY SCHEMES, SANITATION INCLUDING
DISPOSAL OF SOLID AND LIQUID WASTE MANAGEMENT,
WATERHARVESTING AND CHANGE MANAGEMENT”**

COMMUNICATION & CAPACITY DEVELOPMENT UNIT

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CHAPTER – 1

RURAL WATER & SANITATION

– *A SECTOR NEED IMPORTANCE*

Rural Water Supply and Sanitation

Some 70 per cent of the world's poor live in rural areas, so a focus on rural water supply, sanitation, and hygiene is needed if the Millennium Development Goals (MDGs) are to be met. Much has been learned about how to make investments in rural water supply and sanitation effective and sustainable. First, decentralizing management to the lowest appropriate level, coupled with close community involvement in planning, financing, implementation, and operations provides a solid foundation for sustainable services. Second, implementing rural Water Supply and Sanitation (WSS) within a broad development context allows institutions to respond to and support a range of community needs *in a* cost-effective and holistic manner. Third, integrating sanitation and hygiene measures into rural WSS projects ensures that health benefits from increasing water supply coverage are realized. Fourth, addressing post-construction sustainability ensures that institutions, funds, and expertise are available to keep rural water supply systems viable and functional.

Community Management

Rural water supply and sanitation (WSS) investments flow through both dedicated rural WSS investments and multi-sector programs in which communities have chosen rural WSS among other development options.

Community Driven Development (CDD) treats poor people and their institutions as assets and partners in the development process and gives communities responsibility for managing investments. Poor and marginalized people have often been viewed as the target of poverty reduction efforts. Community Driven Development (CDD) approaches turn this perception on its head, and treat poor people and their institutions as assets and partners in the search for sustainable solutions to development challenges. CDD - broadly defined - is an approach that gives control over planning decisions and investment of resources to community groups and local governments. CDD programs operate on the principles of local empowerment, participatory governance, demand-responsiveness, administrative autonomy, greater downward accountability, and enhanced local capacity. Experience has shown that given clear rules of the game, access to information and appropriate capacity and financial support, poor men and women can effectively organize in order to identify community priorities and address local problems, by working in partnership with local governments and other supportive institutions.

Key Challenges in CDD

- Poor and marginalized people are often viewed as passive targets of poverty reduction efforts but today many are expected to take responsibility for managing and maintaining rural water supply facilities.
- Special care should be taken that gender equality issues are addressed in community management in WSS, since women are often the main users of water and since in some communities they are not expected to make their voices heard.
- With community management being implemented by a broad base of stakeholders often working outside the WSS sector, keeping implementation up to date on key principles and national plans for scaling up service delivery is a key challenge.

Rural Water Supply and Sanitation Institutions

By now, rural water supply and sanitation (WSS) is often an integral part of national development strategies. Major changes are taking place in roles and responsibilities, posing unprecedented needs for capacity building, including within rural community organizations. As permanent bodies that are able to engage easily with communities, local governments are taking the lead in managing rural service provision, while communities often assume ownership of rural WSS assets, along with responsibility for providing services and ensuring the management of operations and maintenance. National sector agencies are increasingly decentralizing their implementation responsibilities and taking on the role of facilitators, helping to create an enabling environment for service delivery. National entities outside the WSS sector, such as ministries of finance and planning, are becoming more involved in this facilitation process.

Rural WSS institutions at all levels have key roles to play in optimizing the delivery of sustainable services. Key challenges in the decentralization process are the lack of capacity and the political economy of institutional reform.

Political commitment is needed both inside and outside the WSS sector to enable organizational change. Many local governments lack the human resources or expertise needed to carry out expanded responsibilities, while central agencies often find it difficult to change their role in WSS from implementer to facilitator. Successfully decentralizing service delivery usually calls for technical assistance to address capacity constraints, alongside broad institutional reforms. An essential element in achieving better-managed rural water systems is the promotion of local private sector participation in management, provision of equipment, and maintenance.

Sanitation & Hygiene

Sanitation is vital for human health, generates economic benefits, contributes to dignity and social development, and helps the environment. But worldwide, 2.6 billion people have no access to basic sanitation and hygiene. This lack has been identified as a fundamental component of poverty; it contributes to two million child deaths a year, reduces school attendance, and is a fundamental deprivation of human dignity. Sanitation promotion focuses on stimulating demand for ownership and use of a physical good. Access to basic sanitation refers to access to facilities that hygienically separate human excreta from human, animal, and insect contact. Hygiene promotion focuses on changing personal behaviour. Both are essential to maximize the benefits of investments in clean drinking water.

Target 10 of Millennium Development Goal (MDG) 7 is to halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation.

Financing

Efforts to scale up sustainable rural water supply and sanitation (WSS) services require predictable financing and robust delivery mechanisms. Several key principles underpin financing for sustainable rural WSS:

- Promote increased capital cost recovery from users
- Require an upfront cash contribution based on willingness to pay
- Recover 100 percent of operation and maintenance costs. Usually this calls for improving community level financial management and resource mobilization, especially for major repairs/replacements and service expansion

-
- Have financing mechanisms (public and private sector) and financial intermediation options (such as household credit for on-site sanitation) in place, to help increase internal resource mobilization

Provide detailed information on costs to allow for informed choice, and seek to reduce investment costs through lower-cost technology options and more efficient delivery mechanisms.

Key Challenges

The challenge facing the sector today is how to scale up these experiences in order to meet the MDGs. Increased financing is clearly needed, but so is client capacity to implement and ensure the sustainability of investments. Progress can be made by moving to programmatic approaches, with donors harmonizing their use of support instruments and aligning them within government-designed development strategies. Such an approach can enable wide-scale sector reform, improve the predictability of financing, remove externally imposed bottlenecks, and optimize the impact of both government and external agency support.

Even where there is general agreement and evidence on the economic and health benefits of adequate sanitation services, there is not always an effective demand for action. Governments' limited spending on sanitation often reflects political, more than technical or economic, constraints in the context of competing demands for resources. Planning for sanitation, waste water treatment possesses complex challenges: long-term strategies and investments in sanitation and waste water management are needed as well as emergency responses to frequent floods and droughts. To respond effectively requires: Sound policies based on the development of demand- responsive and community-driven services matched to available resources; expansion of the menu of services and technologies; and inclusion and expansion of hygiene promotion. Development of management capacity at the national, regional, and community levels; and support to the local private sector to deliver and manage sanitation services. The actions that need to improve the Rural WSS includes:

Policy Advice: Govt. or special purpose vehicle need to provide advice on water-related policies and programs through analytical and advisory work and policy dialogue to various rural governments.

Capacity Building; Rural Governance driven agendas have to lead a parallel emphasis on learning and capacity building for groups and individuals to strengthen the organizations in which they work.

Working with Partners: Institutions need to increasingly work with partners from multilateral and bilateral agencies, but also agencies within civil society and the private sector at the global, regional, and country levels.

CHAPTER – 2

2. WATER SUPPLY PRINCIPLES

This Chapter contains the basic design criteria of SVS schemes and MVS schemes, basic principles for rural water supply systems, significance of water quality and quality standards.

2.1. Design Period

Project Components may be designed to meet the requirements of the following design periods.

- | | |
|------------------------------|-----------|
| 1) Storage tanks | 20 years. |
| 2) Infiltration works | 20 years |
| 3) Pump house civil works | 20 years |
| 4) Pumps and Electric motors | 10 years |
| 5) Water Treatment units | 10 years |
| 6) Clear Water Reservoirs | 10 years |
| 7) OHBR/OHSR/GLSR | 10 years |
| 8) Pumping main | 20 years |
| 9) Distribution System/ | 20 years |

Transmission lines

- 10) Land: It is advisable to acquire land for future expansion of components at the time of initial planning.

2.2. Design Criteria of Single Village Schemes

The per capita supply of water shall be 40 LPCD, which excludes 5 to 10 LPCD towards transmission losses in the network. In fluoride-affected areas or in water scarcity areas the minimum per capita supply can be modified after discussions with the community, keeping in view of the requirement of water for drinking and other uses.

The design periods are:

- | | |
|--------------------|----------|
| Source | 20 years |
| Pump sets | 10 years |
| Service Reservoirs | 10 years |
| Pipelines | 20 years |

The stand posts/public taps where demanded by the community shall be provided at the rate of 1 for every 150 persons. In normal practice they shall be provided at the rate of 1 for every 250 persons.

In RWS&S department, at present estimates for single village schemes are being prepared taking 16 hours of pumping in the design of pumping main, pump sets and 8 hours of distribution in the design of distribution lines. The consultant has contacted field staff of RWS&S department and AP Transco field officials. It is informed that 3-phase power supply in rural areas is normally available through out the year for 7 hours only, in two spells of approximately same duration in the morning and evening hours. The honourable Chief Minister of Andhra Pradesh has announced 9 hours of 3 phase power supply for rural areas in this year. Due to gas availability in the Krishna Water Basin and nuclear power plants being proposed by Government of India, additional power is likely to be added in the near future. Since the government is planning to give 12 hours of supply for 3 phase in rural areas in the coming years, it is proposed to adopt 12 hrs in the design of pump sets and pumping main and 8 hours for distribution lines in the project. If 16 hours of 3-phase power supply is available, the SVS schemes are to be designed for 16 hours of pumping.

The sources for SVS schemes are mostly bore wells. When design is done with 12 hours of pumping, the yield of the bore well may or may not give required LPM. Hence yield test of the bore well is to be necessarily conducted to assess the yield. Testing procedure is, first SWL is to be measured, then start pumping with some known discharge which is approximately equal to the discharge measured while drilling, test the level for every 15 minutes of pumping till a constant level of water is maintained in the bore well which is the draw down level. Then total discharge in the bore well can be computed. When the pump is stopped the recuperation in the bore well starts and time is to be noted, while water level comes to the original level, which is the recuperation time of the bore well. This test may be repeated with some increase in discharge for 100 minutes till draw down level maintains constant. Testing may be repeated till there is substantial fall in the draw down level. The yield of the bore well is that maximum discharge where draw down level almost remains constant. If SWL level is 10 mt, draw down level is 70 mt, optimum draw down is 2/3 of the difference which is 40 mt. **Rate of pumping should not be more than safe yield of the bore well.**

During design phase after conducting yield test, yield of the bore is taken in the design of pump set and pumping main for 12 hours of power supply. If single source is not yielding required demand of the community, the community has to go for additional sources so that they get full demand. If single source yields the required demand, then the pumping main and pump sets are to be designed for single pump set and pumping main for 12 hours of power supply.

Capacity of OHSR shall be calculated by mass-curve method keeping in view the realistic availability of electricity and water supply hours.

Staging height of OHT (OHSR) - The tank can be located such that minimum residual pressure in the village is at least 7 meters. If elevated lands are available at a reasonable distance, ground level reservoirs can be proposed for storage of water. If such location is not available an elevated service reservoir can be proposed with staging such that it gives a minimum residual pressure of 7 meters after counting for loss of head during peak hours due to simultaneous opening of all taps on the distribution system.

Size of inlet pipe to OHT = Diameter of pumping main.

Size of outlet from OHT = Diameter of first pipe from OHT to distribution system.

Size of overflow pipe = Inlet pipe diameter.

Size of scour pipe = Half diameter of inlet pipe.

Design of distribution system –The distribution lines are to be designed for a period which is equal to half of available power supply time i.e., 8 hours period. The peak factor shall be accordingly 3(24/8)

The size of distribution pipe line shall also be calculated on the basis of number of connections to be drawn from the pipe, by using the following formula:

$$\text{Number of connections} = [D^5/d^5]^{0.5}$$

Where D is the diameter of main pipe and d is the diameter of branch pipe

e.g. If diameter of main pipe is 150 mm and branch pipe is 90 mm then number of branch pipe connections = 3.58 (say 3)

The design velocity in the distribution system shall normally be not less than 0.6 m per second to prevent silting in the pipes. Size of pipe shall also be checked for number of household private connections and stand posts to be proposed on the branch line using the above formula. For high level and low-level areas, separate feeders shall be provided or proper zoning shall be done in the network. The community will be provided house connections at their cost using GI/PVC pipe of 15 mm diameter. Ferrules shall be used for every house connection.

2.3. Design Criteria of Multi Village Schemes (MVS)

When the Ground water Sources in Villages do not satisfy the quantity and quality requirement, then Multi Village Schemes are to be adopted with sources as surface waters.

The raw water demand is 50 lpcd, which includes losses and treatment wastages. The Per Capita supply of Clear water shall be 40 lpcd.

The different components and their Design periods are as follow:

Source	:	Surface Water sources are generally Canals / Rivers, when the source is not perennial an artificial Impounding Reservoir shall be designed for lean period.
Raw Water Collection Well	:	Capacity of Raw water collection well shall be fixed based on pump set sizes to be accommodated.
Summer Storage Tank	:	The Summer Storage tanks (Artificial impounding reservoirs) are to be provided considering the lean period / canal closure period. To be designed for ultimate demand i.e. 20 years period.
Treatment units	:	<p>Treatment units are designed for prospective demand i.e. 10 years period. When turbidity is low (less than 30 NTU) and when the capacity of unit is less than 3 MLD, then Slow Sand Filters are to be designed.</p> <p>When turbidity is high (more than 30 NTU) and when the capacity of unit is more than 3 MLD, then Rapid Sand Filters are to be designed.</p>
Sumps	:	Clear water sumps are designed for 150 minutes storage capacity.
Pump sets	:	The Raw Water pump sets and clear water pump sets are to be designed by obtaining characteristic curves from the pump suppliers by furnishing head and discharge of each pump location. One stand bye pump set is to be provided at each pump location. To be designed for prospective demand i.e. 10 years.
Power Supply	:	Dedicated power supply lines are to be provided form the nearest Sub station to have an uninterrupted power supply.
OHBR	:	The capacity of OHBR shall be for 30 minutes storage capacity. However provide 90 KL to avoid empty condition. The staging of OHBR shall be such that it should fill all the OHSRs simultaneously.
OHSR	:	<p>Service reservoirs are designed for prospective demand i.e 10 years. The capacity of OHSR shall be calculated by mass curve method. The tank shall be located such that minimum residual pressure in the village is at least 7.0 mts. If elevated land is available at a reasonable distance, ground level service reservoir can be provided for storage of water.</p> <p>Size of inlet pipe is dia of Pumping main feeding the OHSR</p> <p>Size of outlet pipe is dia of pipe of distribution line at the OHSR</p> <p>Size of over flow pipe is dia of inlet pipe at the OHSR</p> <p>Size of scour pipe is half dia of inlet pipe at the OHSR</p>

Pumping main	:	From source to treatment units the pumping mains are to be designed for 20 hours of power supply. From clear water sump to OHBR the pumping mains are to be designed for 20 hours of power supply. The pipelines for pumping mains are to be designed for ultimate demand i.e. 20 years.
Transmission lines	:	The Transmission lines from OHBR to OHSRs will also be designed for 20 hours of power supply.
Distribution System	:	The distribution system shall be designed for ultimate demand i.e. 20 years. The Distribution System from OHSRs to village to be provided for 8 hours supply (peak factor of 3). The design velocity of the distribution system shall not be less than 0.60 m/s to prevent siltage of pipeline.

2.4. Population Forecast

The design population will have to be estimated with due regard to all the factors governing the future growth and development of the project area in the industrial, commercial, educational, social, administrative, and pilgrimage/Tourist aspects.

For proper assessment of population fore cast, following five methods are generally adopted.

Arithmetical Increase method

This method is based on the assumption that population increases at constant rate. A Constant increment growth is added periodically, based on the past records. This method generally gives a low rate of population growth and can be suitable for villages where the growths are not conspicuous and practically controlled.

The formula for population fore cast is

$$P_n = [P_o + N \cdot X]$$

P_n = Prospective or Forecast Population after N decades from the last census.

P_o = Population of last known census

N = Number of decades between now and future.

X = Average of population increase in the last 3 or 4 decades.

Geometrical Increase Method

In this method, percentage increase or percentage growth rate per decade is assumed to be constant, and the increase is compounded over the existing population every decade. This method normally gives larger values of population and is used for areas with unlimited scope for expansion and where a constant growth rate is expected.

The formula for population fore cast is

$$P_n = P_o[1 + R/100]^n$$

P_n = Prospective or Forecast Population after N decades from the last census.

P_o = Population of last known census

n = Number of decades between now and future.

R = Assumed growth rate.

Incremental Increase Method

In this method, the average of the increase in population is taken as per arithmetic method, and to this is added the average of the net incremental increase, once for every future decade whose population is to be estimated will be calculated from the available data. To the present population, the average incremental increase per decade is added and the population of next decade is obtained. Like this, the process is repeated till the population in the desired decade is determined.

The formula for this method is

$$P_n = P_o + nX + [n(n+1)]^{Y/2}$$

P_n = Prospective or Forecast Population after 'n' decades from the last census.

P_o = Population of last known census

n = Number of decades between now and future.

X = Average of population increase in the last 3 or 4 decades.

Y = Average of incremental increase of the known decade.

Graphical Method

This method involves the extension of the population-time curve into the future based on a comparison of a similar curve for comparable areas and modified to the extent depending on the factors governing such predictions. The method has a logical background, and if statistics of similar villages are available, quite precise and reliable forecast can be made. However, it is very difficult to get identical villages with respect to population growth.

Population forecast for Semi-Urban Areas

It has been observed that growth of population in rural areas near main cities grow at higher rate than the rate of growth for other villages. These areas fall under the Semi-urban area category. It is proposed that in all rural areas falling under a radial distance of 5 Km from Class A and B cities population growth rate shall be calculated by Graphical Comparison method. In case no such comparison is available then population growth rate of such areas shall be determined by using Geometrical method.

Final Prediction

The 2001 census shall be taken into account in calculation of population fore cast. The design of rural water supply schemes shall be based on actual existing population with realistic projection for the project assuming the methods described above or growth rate of 1% per year may be adopted.

2.5. Per Capita Supply

While designing a water supply scheme for a village it is necessary to determine the water demand of the village and to find out the suitable water source from where the demand can be met. In Rural Water supply Schemes only domestic water demand is taken for design. The details of the domestic water consumption as per IS 1172-1983 are as follow for one day per capita.

The Government of Andhra Pradesh as per the ARWS norms in designing water supply schemes is adopting 40 lpcd in rural areas for humans to meet the following requirements based on minimum need as defined under the ARWSP Guide lines to cover all the NC,PC habitations as shown in table 2.1. The existing bore wells will augment the water supply in the villages for needs other than drinking.

TABLE:2.1

Purpose	Quantity (LPCD)
Drinking	3
Cooking	5
Bathing	15
Washing utensils and house	7
Ablution	10

In fluoride-affected areas or in water scarcity areas, the minimum per capita supply can be modified after discussion with the community. In some areas, if fluoride free water is to be transmitted over long distances, it may be expensive to operate and maintain and the community may not be able to afford the high user charges. In such cases, the feasibility of dual policy with reduced per capita supply of fluoride free water for cooking and drinking only and supply of fluoride water for all other uses as mentioned above with appropriate per capita supply can also be considered.

2.6. Quality of Water

Pure water is colorless, tasteless, and odourless. It is an excellent solvent that can dissolve most minerals that come in contact with it. This is the reason that there is really no such thing as “pure water” in nature; it always contains chemicals and biological impurities. The water found in nature contains a number of impurities in varying nature in varying amounts. The rainwater which is originally pure, also absorbs gases, dust and other impurities while falling. This water when moves on the ground further carries silt, organic and inorganic impurities. The ground water contains excess fluoride, nitrates etc in certain areas.

The water before supplying to the public should be treated and purified. The palatable water should be free from colour, odour and taste. Water that is contaminated is mainly responsible for the transmission of several waterborne diseases. The following are some of the diseases transmitted by contaminated waters as well as diseases associated with lack of personal cleanliness, environmental hygiene and due to non-availability of wholesome water.

- Acute Bacterial Conjunctivitis
- Amoebic Dysentery
- Hookworm disease
- Cholera
- Dengue, Malaria and Fever
- Gastrointestinal disorders including gastritis
- Relapsing fever
- Scabies
- Fluorosis or mottling of teeth due to excess fluoride
- Dental cavities due to absence of fluorine
- Nitrate Cyanosis in children due to excess nitrates
- Metallic poisoning due to presence of Zinc, copper and lead.

Attributes of Drinking Water

The community’s drinking water shall be

- Free from disease producing organisms
- Colorless and Clear

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- Palatable, i.e., tasty and free from odours,
 - Reasonably soft (not hard)
 - Not causing scales or corrosion
 - Free from objectionable substances such as hydrogen sulphide, iron, and Manganese;
 - Unpolluted by substances in quantities that are toxic or have adverse physiological effects and available in adequate quantities.

Definitions

While describing water quality, certain terms are frequently used which are to be clearly understood and correctly used. Some commonly used definitions are given below.

- **Water Pollution:** It is the introduction of substances in sufficient quantity that affects the original acceptable quality of water, making it objectionable to sight, taste and smell and hence making it less useful.
- **Water Contamination:** It is the introduction of toxic materials, bacteria, or other deleterious agents into water that make the water hazardous and therefore making it unfit for human use.
- **Safe Water:** It is the water that can be consumed without menace to the health of the consumer. Sometimes the word pure water is used which is incorrect, in the sense that there exists no pure water.
- **Potable water and wholesome water:** Potable water is the water that is satisfactory for drinking purposes and from the standpoint of its chemical, physical and biological character and is also known as 'wholesome'.
- **Palatable Water:** It is the water that is appealing to the senses of taste and sight but palatable water need not always be potable.
- **Water in natural State:** Water in nature is never 100% Hydrogen and Oxygen and always contains mineral matter in solution or suspension or dissolved gasses.
- **Parts per million (ppm) or milligrams per litre (mg/l):** These terms are used to the concentrations of dissolved or suspended matter in water. The parts per million is a weight-to-weight relationship. Except in highly mineralized water this quantity was same as mg/l. This is preferable since it indicates how it is determined in the laboratory.
- **pH of Water:** It is an indication of the hydrogen ion concentration in the water. Alkaline will have pH above 7, while acidic water will have pH of below 7, whereas water equal to 7 is neutral.
- **Toxic:** It is a harmful, destructive, or deadly poisonous chemical.
- **Physiological Effects:** These are the effects which change the normal functions of the body of living beings
- **Pathogens:** These are the disease-producing bacteria present in water.
- **Bacteria:** These are groups of universally distributed, essentially unicellular organisms, lacking chlorophyll.
- **Coli form Bacteria:** These are groups of bacteria predominantly inhabiting the intestine human beings and animals but also occasionally found their presence elsewhere due to pollution of water by sewage.

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- **Enteric:** Having its normal habitation in the intestinal tract of human beings or animals.
 - **Virus:** The smallest form of bacteria capable of producing disease in human beings.
 - **Chlorine Residual:** chlorine remaining in the water at the end of a specified period
 - **Chlorine Demand:** The difference between the amount of chlorine added to the water and the amount of residual chlorine remains in the water at the end of a specified period.

The quality of drinking water affects health of the consumers because certain diseases and toxic chemical compounds may be transmitted by water. Experience has shown that community health and supplied water qualities are directly related to each other and that an improvement of water qualities of drinking water supply is followed by an improvement in the community's health. Hence, the water supply systems shall provide water that is safe and available in adequate quantity. A water supply engineer is expected to know what diseases are waterborne, what toxic chemicals are and how they get into water supplies.

2.7. Water and Health of community

Community's health is affected by drinking water quality because

- i) Certain disease causing bacteria are enteric and survive long enough in water to infect water users.
- ii) The excreta of human beings and warm -blooded animals contain bacteria harmful to human beings, and these bacteria can find their way into drinking water sources.
- iii) Chemical substances affecting the health of people can also enter drinking water sources.

Natural water

Water free from both bacteria and dissolved chemicals is seldom found in nature. Water falling as rain, snow or hail washes impurities out of atmosphere; some of these may be present as solids or some may be dissolved. The first water that falls tends to be higher in material removed from atmosphere than that falling later. Even prolonged rainfall may not completely clear the air, rainwater and snow may have dissolved solids as high as 150 mg/lit and total hardness up to 40 mg/lit. In industrial areas due to air pollution carbon dioxide dissolves into rainwater. This phenomenon is known as Acid rain. Normally, the pH value of rainwater is 6.7 to 6.9. Rainwater is also saturated with dissolved oxygen from the atmosphere.

Environmental significance of water quality

Water that is clear and colorless gives an impression that, it is safe for human consumption. This may not be correct, since both disease causing bacteria and objectionable matter may be present but invisible to naked eye. Water quality parameters are classified as physical, chemical and biological nature. The environmental significance of some common parameters of water quality is given below:

2.8. Physical Parameters

- i) **Turbidity:** Any turbidity in water is associated with pollution and associated with health hazards arising out of it. Increased turbidity makes treatment difficult and costly due to increase in chemical coagulation costs and increased frequency of cleaning the filters. In turbid waters the pathogenic organisms may be trapped in the turbid particles and hence protected by

disinfectant. Ground water is less likely to contain turbidity. Turbidity of surface water may settle down by plain sedimentation.

- ii) **Colour:** Natural colour may be acquired by water from decay in swamps and forests, but the colour may not be harmful. The fact is that if the potable water is having color and hence aesthetically not acceptable, the consumers tend to seek water from other sources, which may not be safe. Ground water is less likely to contain colour and surface water may contain color due to industrial activity. However colour is not removed in conventional treatment adopted in Rural Water Supply Schemes.
- iii) **Taste and Odour:** Both should not be noticeable to consumers. Taste is not measurable but should not be objectionable. For odour, Threshold Odour Numbers (TON) is given to indicate the dilutions required for the odour to disappear. It should be preferably one and not greater than three. Alkaline materials impart a bitter taste to water, while metallic salts may give a salty or bitter taste. Organic material, on the other hand is likely to produce both taste and odour. However, odour is not removed in conventional treatment adopted in Rural Water supply Schemes.

2.9. Chemical Parameters

- i) **Nitrates:** Nitrates in water may be due to ‘agricultural run off’ of water source, due to fertilizer use, leaches from septic tanks, sewage and erosion of natural deposits. Excessive amounts of nitrates in drinking water causes ‘blue baby syndrome disease in infants under six months. However, Nitrates are not removed in conventional treatment adopted in Rural Water Supply Schemes.
- ii) **Total Dissolved Solids (TDS):** Total dissolved solids in natural water are due to inorganic salts. Classification of water into fresh, brackish, saline and sea water is usually based on the content of TDS.
- iii) **Dissolved Oxygen (DO)** is of significance in corrosion of iron and steel particularly in distribution systems. However DO is not removed in conventional treatment adopted in Rural Water Supply Schemes.
- iv) **Fluorides:** Minimum of 1mg/lit. may be required to prevent dental carvities, but beyond 1.5 mg/lit may cause staining of teeth/dental fluorosis and also skeletal fluorosis. Treatment units set up in India for removal of excessive fluorides in Rural Water supply schemes are so far not functioning satisfactorily.
- v) **Iron:** Iron may be present in water as a dissolved impurity from the earth’s crust or enters the water from corroded pumps and pipes. Excess iron may cause staining of clothes during washing, stains on plumbing fixtures and encrustation and deposits on the interior surfaces of the pipe.
- vi) **Manganese:** Manganese at lower concentrations causes troublesome deposits in mains. However, Manganese is not removed in conventional treatment adopted in Rural Water Supply Schemes.

Trace elements

- i) **Barium:** Even at 1 mg/lit, it causes muscular and cardiovascular disorder and Kidney damage.
- ii) **Cadmium:** At low levels and exposure for prolonged periods it causes high blood pressure, sterility among males, kidney damage and flu like disorders.

- iii) **Chromium:** Beyond 0.05 mg/lit is carcinogenic
- iv) **Copper:** Beyond 0.05 mg/lit, it is found to be toxic to fish
- v) **Lead:** Beyond 0.05 mg/lit, it causes brain and kidney damage. In youngsters it may cause mental retardation.
- vi) **Mercury:** At very low concentration it forms ethylated mercury compounds, which are toxic to human beings and fish.
- vii) **Silver:** Has no adverse effect but silver salts are good disinfectants.
- viii) **Arsenic, Selenium & Cyanide:** They are toxic and carcinogenic.

However, trace elements are not removed in the conventional water treatment plants, which are normally provided in the Rural Water Schemes.

2.10. Biological Contaminants

- i) **Bacteria:** Diseases caused by water borne bacteria are always intestinal and include dysentery, cholera and gastro-enteritis.
- ii) **Viral:** Infectious hepatitis may be waterborne.

Slow sand filtration may remove bacterial and viral contaminants. However, disinfection makes the water wholesome. The drinking water required to the community shall conform to the relevant clauses so as to minimize health hazards to the community. The quality of water supplied shall satisfy the criteria contained in the CPHEEO manual and are given below

2.11. Water quality standards - Norms for Acceptance

The physical and chemical quality of drinking water should be in accordance with the WHO guidelines and CPHEEO manual and are shown in table 2.2.

TABLE: 2.2

S. No	Characteristics	Acceptable	Tolerance limits	Rejection	Remarks
1	Turbidity NTU	1	2-9	10	Consumer acceptance decreases
2	Color (Units on Platinum cobalt Scale)	5	6-24	25	
3	Taste and Odour	Unobjectionable		Objectionable	
4	pH	7-8.5		<6.5 and >9.2	Water will effect the mucous membrane and water supply system
5	Total Dissolved Solids mg/lit	500	501-1999	2000	Consumer acceptance decreases. May cause gastro intestinal irritation.
6	Total hardness as CaCO ₃ in mg/lit	200	201-599	600	Encrustation in water supply structure and adverse effects on domestic use/scale formation
7	Chlorides (as CL)(mg/l)	200	201-999	1000	Taste, palatability and corrosion are affected.
8	Sulphates (as SO ₄) (mg/l)	200	201-399	400	Causes Gastro intestinal

					irritation
9	Fluorides (as F) (mg/l)	1.0	1.0-1.5	1.5	Results in dental / skeletal fluorosis
10	Nitrates (as NO ₃) (mg/l)	<45	-	>45	May cause Methaemoglobineamia / Blue baby disease
11	Calcium (as Ca) (mg/l)	75	76-199	200	Encrustation in water supply structure and adverse effects on domestic use
12	Magnesium (as Mg) (mg/l)	<30	31-149	150	
13	Iron (as Fe) (mg/l)	0.1	0.2-0.9	1.0	Taste and appearance are affected and promotes iron bacteria and adverse effect on domestic user and water structures
14	Manganese (as Mn) (mg/l)	0.05	0.05-0.5	0.5	
15	Copper (as Cu) (mg/l)	0.05	0.05-1.5	1.5	
16	Aluminum (as Al) (mg/l)	0.03	0.04-0.19	0.2	
17	Alkalinity (mg/l)	200	201-599	600	Water will affect the mucous membrane and / water supply system, taste becomes unpleasant
S. No.	Characteristics	Acceptable	Tolerance limits	Rejection	Remarks
18	Residual Chlorine (mg/l)	0.2	0.3-1	>1.0	
19	Zinc (as Zn) (mg/l)	5.0	6-14	15.0	
20	Phenolic Compounds (mg/l)	0.001		0.002	
21	Anionic Detergents (mg/l)	0.2	0.3-0.99	1.0	
22	Mineral Oil (mg/l)	0.01	0.02	0.03	

S. No.	Characteristics	Acceptable	Tolerance limits	Rejection	Remarks
Toxic Materials					
23	Arsenic (mg/l)		0.02-0.04	0.05	Water becomes toxic
24	Cadmium (mg/l)	<0.01	-	>0.01	
25	Chromium (mg/l)	<0.05	-	>0.05	
26	Cyanides(as CN) (mg/l)	0.05	-	0.05	
27	Lead(as PB) (mg/l)	0.05	-	0.05	
28	Selenium(as Se)(mg/l)	0.01		0.01	
29	Mercury (total as Hg) (mg/l)	0.001		0.001	
30	Polinuclear aromatic hydrocarbons (PAH) (µg/l)	0.2		.02	
31	Pesticides (total, mg/l)	Absent			
Radio Activity +					
32	Gross Alpha acitivity (Bq/l)	0.1		0.1	
33	Gross Beta acitivity (Bq/l)	1.0		1.0	

The Bacteriological quality of drinking water should be in accordance with the WHO guidelines and CPHEEO manual and are shown in table 2.3.

TABLE:2.3

Organisms	Guideline value
All water intended for drinking	
Ecoli or thermo-tolerant coli form bacteria	Must not be detectable in any 100-ml sample
Treated water entering the distribution system	
Ecoli or thermo-tolerant coli form bacteria	Must not be detectable in any 100-ml sample
Total coli form bacteria	Must not be detectable in any 100-ml sample
Treated water in the distribution system	
Ecoli or thermo-tolerant coli form bacteria	Must not be detectable in any 100-ml sample
Total coli form bacteria	Must not be detectable in any 100-ml sample. In case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12 months period.

2.12. Virological quality

Drinking water must essentially be free of human enteroviruses to ensure negligible risk of transmitting viral infection. Any drinking water supply subject to faecal contamination presents the risk of a viral disease to consumers. The following table 2.4 shows the guideline criteria based upon likely viral content of source water and the degree of treatment .It is also necessary to disinfect the distribution system to guard against any contamination in distribution system.

TABLE:2.4

Type of Source	Recommended Treatment
Ground water	
Protected, deep wells; essentially free of faecal contamination	Disinfection
Unprotected, shallow wells; faecal contamination	Filtration and disinfection
Surface water	
Protected, impounded upland water; essentially free of faecal contamination	Disinfection
Unprotected impounded water or upland river, faecal contamination	Filtration and disinfection
Unprotected lowland rivers; faecal contamination	Pre-disinfection or storage, filtration, disinfection
Unprotected watershed; heavy faecal contamination	Pre-disinfection or storage, filtration, additional treatment and disinfection
Unprotected watersheds; gross faecal contamination	Not recommended for drinking water supply

2.13. Water Quality Reports

The following are the observations to be incorporated in the tabular form while preparing reports.

- Review of existing water quality status in project villages.
- Details of all existing water supply schemes/ sources (Number of BW/OW/Tanks, etc., working / defunct) with clear markings (painted with blue color for sources and red color for non-potable sources) of the sources in the village geographical/global positioning systems).
- Latest water supply analysis (physical, chemical and biological tests)/ water quantity results of all working sources should be incorporated in the report
- Compare the latest water quality results with old available data (secondary data from Water Supply and Sanitation department) and find out the difference.

Justify the proposed source details from the quality angle. Also mention the distance of this source from the existing potable / non -potable sources

Water Sample Quality Testing and Sample Collection Proforma

- 1) Name and address of person requesting the examination.
- 2) Date and time of collection and dispatch
- 3) Purpose of examination
- 4) Source of water and its location (well, tube well, stream, river, etc.)
- 5) Exact place and depth below surface, from which sample was taken.
- 6) Weather at the time of collection and particulars of recent rainfall, if any
- 7) Does the water become affected in taste or odour after rainfall or under any particular circumstances?
- 8) Are there any complaints from the consumers? If so, the nature of the complaint
- 9) Character of surroundings and proximity to drains, cess pools, cattle sheds, manure heaps, grave yard, bathing ghats and other sources of pollution.
- 10) Methods of purification and disinfection if any, details, dose of chemicals and points of application.

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- 11) If from a dug well or a bore well.
 - (a) Whether an old source or newly constructed
 - (b) Whether open or covered nature and material of cover
 - (c) Nature of steining or casing and depth to which constructed and whether it is in good condition.
 - (d) Height and condition of parapet and apron
 - (e) Method of pumping or other means of raising water.
 - (f) Depth of well and of water surface from ground level.
 - (g) Whether the water is clear if flows out of tube well and remains clear if exposed to air (4-6 hours) or becomes discoloured and turbid.
 - 12) If from a river or stream
 - (a) Nature of flow and whether floods are common or rare
 - (b) Whether level of water is above or below normal
 - (c) Is there any bathing ghat, boat jetty, burial ground and sewer outfall? If upstream, give distance from sampling point.
 - 13) If from lakes, impounded reservoirs and tanks.
 - (a) How supplied (channel, stream, rain)
 - (b) Nature of catchment, whether conserved or not
 - (c) Nature and extent of weed growth
 - 14) Size and number of service reservoirs
 - (a) Whether open or covered
 - (b) How often cleaned and method of cleaning
 - (c) Date of last cleaning
 - 15) Number of hydrants and sewers on the distribution system
 - 16) Hours of pumping and supply.
 - 17) Population served
 - 18) Any other particulars
 - 19) Station

2.14. Water Quality Monitoring

Supply of safe drinking water in adequate quantity to the public is a prime responsibility of a civic body. This task could be achieved if and only if the water supply agency is adequately equipped with necessary infrastructure for routine water quality monitoring and control. Presently, there is no agency with a well-defined mandate for routine water quality monitoring and control of rural water supply in the State. The authority in charge checks the potability of any newly established tube wells/ surface source by conducting all the tests on the water samples collected. If the quality parameters are within the prescribed limits, the source is developed and allowed to be used by the community. If the water does not satisfy the required quality parameters, new bore wells are drilled after conducting detailed geophysical surveys. In areas where ground water is not potable canal based schemes are designed. Raw water is collected from canals and after treatment supplied to the community. It is very important that a suitable mechanism should be adopted to have regular quality surveillance. During rainy season water quality surveillance should be more stringent.

2.15. Water Quality Surveillance:

Laboratories with adequate facilities and manned by qualified personnel are essential for inspection and evaluation of the suitability of water supplies for public use as well as for controlling the water treatment process. The ultimate aim of laboratory examination of water is to ensure that potable water conforming to the drinking water standards is supplied to the consumers.

Objective:

- i) To ascertain the quality of water in various rural water supply schemes (Tube wells or canal based) as well as in the distribution network.
- ii) To examine physical, chemical and bacteriological quality to establish whether the drinking water is fit for human consumption and meets the standards as laid down in IS – 10500: 1991.

Location for sampling: Selection of location for sampling should indicate true representative samples

- i) Public Stand Posts
- ii) Selected consumer location at random
- iii) In addition to above, raw water source and treated water should also be analyzed in case of canal based water supply schemes.

Type of sampling: Generally, for drinking water quality monitoring, grab samples should be preferred

Frequency of sampling: Mainly depends on population served, size, source and type of the scheme is as shown in table 2.5.

TABLE:2.5

Source	Minimum frequency of sampling and analysis		Remarks
	Bacteriological	Physical/Chemical	
Tube well based	Once initially, thereafter as situation demands	Once initially, then 2 times yearly	Situation requiring testing: change in environmental conditions, outbreak of water borne disease or increase in incidence of waterborne diseases.
Canal based	Once monthly	Once initially then 2 times yearly – Residual chlorine test daily	Increase frequency of bacteriological test if situation demands

Precautions shall be taken during collection, preservation and storage of samples

2.16. Review of source water quality

After the water quality report is received the parameters may be compared with the standards and if the water satisfies the standards the same source can be accepted with disinfection only. If fluorides and TDS are present in excess of permissible limits, dilution if possible can be one of the options. Conveying potable water from distant sources either surface or groundwater can also be other option. If nitrates and iron are higher, it is necessary to search for the source of contamination and take remedial measures. However, treatment of such water for removal of iron and nitrates is not a viable option in villages. If the contamination is not traceable and if the presence of iron and nitrates is due to natural acquisition, then another source is to be selected. Use of PVC casing pipe avoids corrosion, also extending the casing pipe up to 12 m will enable prevention of ingress of nitrates. Treatment for removal of fluorides and iron shall be the last option since the rural community cannot operate and maintain such treatment plants.

Adequately equipped analytical laboratory with competent analysts is an important and an integral part of any water quality monitoring and surveillance programme. The analytical determinations of different physical, chemical, biological and bacteriological parameters must be carried out most efficiently and accurately. However, the laboratory infrastructure needed shall necessarily depend upon the level of analysis desired, location and other support facilities available.

Realizing the need to institutionalize water quality monitoring and surveillance system, Government of India in Rajiv Gandhi National Drinking Water Mission has formulated an implementation plan based on three-tier structure or catchments area approach where existing resources available with grass root level education and technical institutions would be utilized. In case of need be, these institutions would further be strengthened by providing additional financial sources.

Village level: Water quality surveillance (WQS) exists at the village level. Water quality monitoring is felt need of the people, as in rural areas they perceive water supply as demand. To make the WQS programme more effective, under WQS Programme, field kits for both chemical and bacteriological analysis would be provided to 10+2 schools having science stream or in the primary rural Health Centers. These field kits would mainly indicate the presence of turbidity, pH, hardness, chloride, fluoride, iron, residual chlorine and bacteriological quality. The field kit will be basically meant for qualitative assessment of water and would help to identify unsafe drinking water supply system immediately. In case, water is unfit for drinking, samples would be sent for detailed investigations to the district labs.

District Level: All District level labs are already functional,

State level: One State Level water quality testing laboratory is required

Further for facilitating effective water surveillance programme, a mobile water testing laboratory is also being proposed under the control of RWS&S as this would help in identification of source of contamination as well as for identifying new potential water sources, besides it would also impart training to village and district level laboratory staff. The mobile laboratory would be fully equipped to carryout on the spot analysis of water and would be equipped with small fridge, hot air oven, water bath and incubator.

2.17. Types of Sources for Water Supply

After estimating the required quantity of water for the proposed water supply scheme it is necessary to search for a nearby water source, which may be able to supply the required quantity and quality of water. If the available source doesn't supply required quality and quantity of water, then it is necessary to choose another water source at some other distant location.

The origin of all sources of water is rainfall. Water can be collected as the various sources of water available on the earth are as follows.

- a) Surface sources such as Ponds, Lakes, Rivers, Streams, Canals, Storage reservoir and Oceans.
- b) Sub Surface Sources such as Bore wells, Open wells, Springs, Infiltration wells and infiltration galleries

Most of the earth's water sources get their water supplies from precipitation, which may fall in various forms such as rain, snow, hail, dew etc. Rain is the principal source and major part of supplies.

Surface Waters

Surface Schemes shall be designed only where the following conditions prevail:

1. Where ground water is insufficient or having quality problem such as high fluorides /high TDS
2. For the surface schemes to become viable the number of villages must be at least of 3. However lack of cooperation among the villages may create problems in operation and

hence affect supply to the villages beyond the source. Hence this aspect is also to be considered before a surface scheme is proposed.

3. Since the cluster of villages requiring surface water has to be large to make the scheme viable, some en-route villages (Which do not have quality problem) can also be clubbed with the surface scheme. However, with increasing number of villages, communication problems may affect operation and maintenance.

Surface Sources of water include rivers, streams, lakes, ponds etc .The water in lakes, rivers and ponds are collection of rainwater and base flow. The water in them will be uniform in quality compared to the flowing water in streams.

Artificial Impounding Reservoirs (Storage and Sedimentation Tanks)

Rural water supply systems are planned with large impounding reservoirs (also called Summer Storage Tanks) as sources. If an existing impounding reservoir is available nearby. it can be used as source for rural water supply also, since construction of impounding reservoirs exclusively for rural water supply scheme will be expensive. Where water is drawn from canal or from a non-perennial river, it may necessary to create a storage reservoir with capacity equal to the closure period of canal or equal to the dry flow period in the river, Usually, the canal closure period of canal is equal to the dry flow period in the river or streams. Usually, the canal closure period will be about 2 months, and the river or streams may be dry for 3-4 months. The raw water from stream / river / canal may have to be pumped over long distances and larger heads for storage in the impounding reservoirs resulting in higher power charges. The capacity of impounding reservoir to be constructed shall be equal to the canal closure period/ dry season of steam or river plus the evaporation and seepage losses. The pumping plant pumping the raw water from the canal / river / stream shall be designed such that the pumps, in addition to pumping the daily requirement will also have capacity to fill the impounding reservoir before commencement of the closure period of the canal or before stream / river goes dry.

The preferred technology option for treatment of surface water for rural communities is plain sedimentation followed by balancing tank, slow sand filtration and disinfection (with bleaching powder), pure water sump or filter water sump. Usually a jack well is constructed in the canal / stream or river and water is pumped to the elevated storage reservoirs for distribution to the villages thus resulting in higher power charges. In view of the treatment cost and higher power charges and larger skilled manpower involved, user charger for supplying treated water from streams and lakes are likely to be higher. Hence, the community is to be informed of the high user charges and their willingness should be obtained for such surface schemes before selecting as technology option.

2.18. Types of Water Supply Schemes

- **Bore Well with Hand Pump:** - When a small group of houses with population is around 250 or less, bore wells with hand pumps are provided for water supply to the concerned community. Bore wells are to be drilled to required depth as per recommendation of Geologist / Physist. Usually 100 to 150 mm dia bore wells with DTH are drilled for a maximum depth of 300 feet and Mark II hand pumps are fixed. Power is not required for this hand pumps.
- **MPWS Scheme:-** In the Mini Protected Water Supply Schemes (MPWSS) the components are bore well, pump set, GLSR and 4–5 taps at the GLSR. The advantage of the MPWS scheme is that the maintenance charges are very less compared to the PWS Scheme. These schemes are provided for the following Conditions.
 - Distribution system is not required.

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- When the Population is very less
 - Houses are situated at one place so that distribution at one point is adequate.
 - If the static water in the bore well is more than 150 feet, and the provision of hand pump is not suitable.
 - Bore well located very near to the distribution point, so that low pumping main.
 - At small pilgrim places where only seasonal functioning of scheme is required.
 - Tribal areas and other remote areas
 - When Capital cost is very less.
- **PWS Scheme for Single Village (SVS):-** When Population of the village is more than 500 , then it is advisable to provide Protected Water Supply (PWS)Scheme or it is called Single Village Scheme(SVS).The Components of the Scheme are Bore well , Pump set, Pump room, Chlorination plant, Pumping main, OHSR ,Distribution system ,Public taps and House service connections. This type of schemes is provided where the yield of bore well is satisfying the quantity and quality norms.
 - **CPWS Schemes:-** Also called Multi Village Schemes (MVS) are provided for group of villages. When the source of some villages is not satisfying the quantity and quality norms, then the villages are clubbed together and a comprehensive Scheme will be designed. The surface water source is selected for these schemes. The components of the scheme are source, Intake well cum pump house, Summer storage tank, Raw Water pump sets, Raw water pumping main, Treatment units (Slow sand filters/Rapid sand filters) Clear water sump, Clear water pumping main, OHBR, Distribution System and OHSR for each village.

2.19. Source Selection

Scientific selection of water sources is more important for the project area since the ground water table has been depleting very fast. Hence, the locations selected for water sources shall be amenable for encouraging ground water into the aquifers. The presence of underground fractures in the geological formations will encourage the seepage of the water into the aquifers. The deeper the fractures better will be the yield. Hence, while doing the geophysical survey for selection of source, particular attention is required to this aspect. The technology has progressed and now there are more reliable methods for conducting geological and geophysical investigations with instruments working on very low frequency (VLF).

The exploration methods that can be adopted to locate the ground water are:

- i) **Geological Methods:** Demarcating the boundary between litho logic units, faults, fractures, fissures, formation characteristics, lineaments & dykes, intrusive and shear zones.
 - ii) **Remote Sensing Techniques:** interpretation of satellite images to locate lineaments and other structural discontinuities, mapping of various hydrogemorphic unit, vegetation, soil and land use and land cover categories.
 - iii) **Geophysical Methods:** Surface geophysical surveys using electrical resistivity, electromagnetic, seismic and magnetic methods to delineate the weak and water-saturated zone.
- **Geophysical Exploration:** Geo Physical methods comprise measurement and interpretation of signals from natural or induced physical phenomenon generated as a result of a sub-terrain formation. These signals measured repetitively at several points of space and time are approximately interpreted, considering the available geological information, in terms of such sub-surface structures/features as may themselves have good

ground water potential or are indicative of good aquifers. Knowledge of the geology of ground water areas is essential to establish the water bearing formulations. Surface geology, exposed due to quarrying, mining etc provide useful information. Well logs of existing wells (records that give the nature and depth of various strata that were encountered during sinking of the wells) also contribute as supplementary information in assessing the nature of the sources being explored.

- **Geomagnetic:** Measurements of variations of gravity and of the earth's magnetic field are made with the aid of the torsion balance and the magnetometer. These instruments do not determine the presence of water itself. They suggest the location of geological structures that may be favorable water carriers.

2.20. Assessment of yield

An accurate assessment of the yield of the source is essential to decide which source can be dependable. The yield of bore wells is to be assessed preferably in the lowest seasonal water level conditions. In Andhra Pradesh, the preferable season for conducting yield test is from February to June, when the summer is at its peak and rainfall has not yet set in. Yield test units are available which can be used to pump out the water from the bore well for a maximum period of six hours at a time. Care should be taken that the water pumped out is led away from the source and does not re-enter the source. The draw down and discharge are measured and the results tabulated from which the safe yield is calculated. The assessed yield is multiplied by a coefficient to arrive at the safe yield from the source to account for the seasonal variations and also to prevent over exploitation from the bore well, which may lead to collapsing of the bore well.

In case the yield test is conducted during non-summer months, a suitable coefficient for assessing the safe yield has to be used. While drilling the bore wells, it is essential that a correct record of the strata of the bore well and the depths of water column are noted in a dated long back and this record must be made available at the GP. Maximum permissible size of pump to be installed in the Tube Well should be clearly mentioned at the wall of the Pump chamber to prevent over pumping from the Tube well.

For assessing the yield from infiltration wells sunk in the riverbeds the same methods as described above is used for determining the safe yield from the source. In the case of canals, the levels at which water can be made available and the quantum of water and the period for which the canal is flowing are used to assess the sizes of various components of the water supply scheme.

- i) Properly labeled sampling bottles to avoid any error.
- ii) No significant change in samples between time of collection and conducting water analysis and samples should be dispatched to lab under iced conditions as soon as practicable.
- iii) Samples should be examined maximum within 24 hours after collection.
- iv) De-Chlorination is prerequisite for sampling for bacteriological examination
- v) No contamination should take place while collecting the sample prior to examination especially for bacteriological tests. For taking sample of water for a tap on distribution system, allow the water to run for 4 to 5 minutes to allow cleaning of service pipe.
- vi) The water sample shall be collected and its data sheet should be filled up along with sample for onward submission to water quality testing lab.

Quantity of sample

- i) For physical and chemical examination – two (2) liters of samples in colorless or pale green bottles.
- ii) For bacteriological examination- 250ml sterilized glass bottles provided with ground glass stopper.

2.21. Service Reservoirs

Capacity of OHSR shall be calculated keeping in view the realistic availability of electricity and water supply hours. Normally in rural areas of Andhra Pradesh electricity is available in shifts on rotation basis. Pumping hours will vary as per availability of electricity. Hence, before fixing the capacity of OHSR the required capacity should be worked out for worst-case scenario. The tank shall be located such that the minimum residual pressure at the remotest point in the village is at least 7 mts. If elevated lands are available at a reasonable distance, ground level reservoirs can be proposed for storage of water. If such location is not available, an elevated service reservoir can be proposed with staging such that it gives a minimum residual pressure of 7 mts after counting for loss of head during peak hours due to simultaneous opening of the all the taps on the distribution system.

2.22. Treatment

Ground Waters, which are free from odour and color and turbidity problems, can be supplied after plain disinfection by chlorinating. Surface waters may require conventional treatment consisting of sedimentation, filtration and disinfection. The treatment proposed for water shall be such that it is easy to maintain and operate by the village community. Presence of fluorides requires treatment to remove fluorides, which is not easy for the community to operate and maintain the treatment scheme. Nitrates and TDS cannot be removed in conventional Treatment System. Iron presence, though amenable, its removal becomes difficult and the plant is uneconomical to the community to maintain. Disinfection of water supply shall be carried out with Bleaching Powder / Sodium Hypo chlorine using diaphragm based dosing pumps. Silver ionization wherever it is viable can also used to carry out disinfection of water supply.

For Surface waters two types of treatments are used

- i) Slow sand Filters
- ii) Rapid sand Filters.

2.23. Transmission Lines

There are two types of transmission lines used in water supply schemes.

- i) **Gravity Pipelines:** Gravity pipelines are those in which the water flows under the action of gravity. These pipelines cannot go up and down through hills and valleys as per the available topography.
- ii) **Pressure Pipelines:** In Pressure pipelines, water flows under pressure above the atmospheric pressure. The pressure pipes can follow natural available ground surface and can freely go up and down through hills and valleys.

Common terms of pressure

- **Working Pressure:** Working pressure may be defined as the actual pressure (including abnormal pressure such as water hammer) to which the pipe will be subjected during its operation.

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- **Design Pressure:** Design pressure may be defined as the maximum pressure for which the pipe has been designed. This is equal to the product of the working pressure and suitable factor of safety to cover the abnormal increase in pressure due to unforeseen circumstances.
 - **Test Pressure:** Test Pressure may be defined as the maximum pressure, which the pipe can withstand without any leakage when tested for hydrostatic pressure in accordance with the standard methods of testing.

2.24. Pipe Appurtenances

In order to isolate and drain the pipeline sections for tests, inspections, leaning and repairs, a number of appurtenances such as sluice valves, scour valves, air valves, reflux valves, manholes, insulation joints, expansion joints, anchorages etc are provided at various suitable places along the pipeline.

2.25. Distribution system

If the project proposes to have piped water supply schemes in all the villages covered in the project, it is expected that there will be substantial demand for individual house connection. Hence, pipe network in the form of dead / loop system (which is mostly suitable for rural areas) shall be planned. For the benefits of community not opting for house connection stand post shall be provided at appropriate places @ one per 150 persons in the villages. However, as explained above the use of stand posts shall be discouraged as it results in avoidable wastage. Normally in rural water supply schemes, the pumping hours does not exceed 8 hours due to constraints of requisite power supply.

2.26. Pumps

Submersible pumps shall be provided for all bore wells and centrifugal pumps/submersible pumps for canal based water supply schemes. While calculating the capacity of pump, resulting suction head, delivery head and frictional losses shall be considered appropriate only commercially available pump capacities shall be adopted in the project.

Normally Standby pumps are not proposed in rural water supply systems based on bore well and for other sources. Standby pumps shall be provided only in exceptional circumstances. Only in such cases, if the number of pumps installed is more than one, then one stand-by pump suggested. For economical selection of the pump, the actual pump capacity required shall be worked out using the family curves furnished by pump manufacturer. However, in arriving economic size of rising main only overall efficiency of pumps can be taken as 40% for submersible pumps and 60% for centrifugal pumps.

2.27. Pump Room

Pump Room is provided to accommodate the pump sets, Accessories of Pump sets, electrical meters, pressure gauges, chlorination plants and any other materials. The Pump Room should be planned considering the above aspects.

CHAPTER – 3

3. EXISTING WATER SUPPLY AND SANITATION STATUS

3.1. Assessment of Water Supply Situation

In Andhra Pradesh most of the habitations are provided with water supply in one form or the other. The technology options for these schemes varies from simple hand pump, mini water supply scheme, piped water supply schemes with ground water source and a few piped water supply schemes with surface water source. These schemes have been executed by the RWS&S Department and have been handed over to the respective GPs for O&M. Some of the rural water supply systems are not functional or working below their designed capacity due to the following reasons

- Failure of sources
- Water quality problems
- Leakage in pipelines & OHSR
- Pump set failures and Power problems
- Depletion of ground water levels
- Poor maintenance by GPs due to funds constraint and lack of interest
- The community is not paying the user charges towards the water consumed by them and the GP has no independent source of income

The present arrangements of maintenance of water supply schemes in the State are as follows:

Hand pumps maintenance is handed over to concerned Mandal parishads, allotting Rs 600 per hand pump per year

- SVS are handed over to GPs for O&M, by collecting user charges
- CPWS schemes are being maintained by Zilla Parishads

In view of this, there is a need to assess the status of the existing water supply system and to estimate the rehabilitation needs so that the systems will become fully functional. Rehabilitation works have to be identified so as to facilitate integration of the proposed water supply schemes with the existing water supply system. The strategy shall be to identify the rehabilitation of schemes into immediate and long term. In the immediate needs, there is no major investment but small additions and proper management may certainly revive the schemes. Some of the works that could be included shall be

- Immediate repairs to pump sets
- Rectification of leakages in pipelines and valves
- Effective supervision

In the long-term needs, additional investments are to be made so as to upgrade the existing system to the desired level. Some of the works that could be included shall be

- Selection of additional sources where quality /quantity of water available in the existing system is inadequate
- Modifications to existing pipelines/pumps or provisions of new pipelines/pumps in case of existing pipelines and pumps are inadequate.

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- Strengthening/restoration of existing storage tanks or provision of new higher capacity tanks/additional tanks to cater for additional storage capacity to meet the designed demand.
 - Additions and extensions of the existing distribution system or provisions of new distribution system where there is no pipeline network/existing pipeline network is inadequate and pipe are crusted due to hard water.
- Scope & extent of ground water recharging measures required for ensuring the source sustainability.

3.2. Assessment of Sanitation Situation

Good number of ISLs are taken up and completed. The problem is with utilization of toilets The problems in sanitation are

- Majority of ISLs are not in use due to various reasons like water supply, drain out wastewater.
- School Toilets and anganwadi toilets are taken up, but due to water supply problems and other problems, the usage and maintenance of toilets is not satisfactory.
- In many habitations open drains are taken up, but in majority of habitations the drains are constructed without planning and design. Ground levels are not taken, storm water calculations are not made, outlet of drains are not planned , the construction was not taken from end to start, no linkage of two drains made , and the quality of construction is not up to the mark. Due improper construction the drains are not functioning, choked up and becoming unhygiene.

3.3. Check list for Rehabilitation of existing water supply scheme

TABLE:3.1

S.No	Attribute	Yes/No
	(A) Source Improvement	
1.	Are present condition, adequacy, potability, yield, draw down etc. known?	
2.	Are the slot portions of sedimentary bore well flushed using chemicals/detergents?	
3.	Is geophysical survey done at the location of bore well for deepening the bore well?	
4.	Is detailed geophysical survey was conducted for hard rock bore well for hydrofracturing?	
5.	Is it necessary to provide alternate bore well, if not possible to improve by the above methods.	
	(B) Replacement of pump sets	
1.	Is it necessary to replace the pump sets for improving the pumping quantity	
2.	Is it necessary to replace submersible pump sets in lieu of Jet pump sets I to meet the demand	
3.	Whether higher duty submersible pump set is suitable, if source is sufficient	
4.	Whether the safe yield in the bore well was assessed with suitable pump to match the safe yield to avoid throttling of existing pump set.	
	(C) Pump Room	
1.	Is it necessary to construct separate pump room for the additional bore well source drilled	
	(D) Pumping Main/Distribution Main	
1.	Whether the condition of pipes of existing pumping main was checked	
2.	Whether scouring was done for each 500 meters reach of entire pipe line, if silt deposited	
3.	Whether the bursts and leaks if any were attended in pipe line and valve pits.	
4.	Whether air and scour valves were introduced.	
5.	Whether the damaged valves were replaced	
	(E) Overhead Tank	
1.	Whether the conditions of existing OHSR was studied	
2.	Whether rehabilitation of structure is necessary for utilizing the OHSR	
3.	Whether additional OHSR is necessary for balance population of unserved area	
4.	Whether the additional OHSR is necessary for high level zone to effect supply for balance population	
5.	Whether it is possible to utilize the existing OHSR even after rejuvenation	
	(F) Public stand posts	
1.	Is the distribution main served areas were inspected along with the GPWSC	
2.	Whether the unauthorized house service connections were removed to save the water	
3.	Whether the hose pipe connected to the taps by the residents were removed	
4.	Whether the pit taps provided by the public were removed and stand post provided near the pit taps.	
5.	Whether the illegal Public stand post were removed	
6.	Whether the ferrules were provided for the public taps and house service connections to restrict the drawl of water	
7.	Whether the existing public stand posts were repaired.	

CHAPTER 4

4. PRELIMINARY PROJECT REPORT

In a demand based approach the village expresses its demand for a water supply scheme .preliminary discussions have to be held with the community about the likely source of the project. Based on the likely source alternate options have to be given to the community based on capital cost and O&M cost .This is done by rough cost estimates of various components

The components of the pre-feasibility Report/Preliminary Project Report are:

4.1. Reconnaissance

A support agency consisting of social scientist, consulting engineer & geologist and the community shall go round the village for collecting the data required for preparation of the Preliminary project report. During the reconnaissance, the functioning of the existing water supply scheme is studied and the rehabilitation needs are noted. For the proposed scheme, the location of the source is to be identified with the consent of the community. The ground water availability and quality of water may be ascertained by studying the water table in the existing sources and discussion with the community. Then the population estimation is to be done in consultation with the community. The future population may be assessed considering all the possible expansions.

A preliminary survey is to be done to assess geographical plans, contour plans and other related geographical and hydrological details. The site inspection should be made to identify the units of water works such as treatment units, service reservoirs, pumping main, distribution system. The highest ground level and the lowest ground level and lengths of various components of pipeline have to be approximately assessed. During the reconnaissance the nature of terrain and soil condition are noted and alignment for the drain leading to the disposal point is also identified and noted on the map. The source of power supply, financial aspects of the community is to be assessed. At the end of the reconnaissance, the extent of rehabilitation and scope of the proposed scheme along with the concept would have been formed.

After collecting the field data, approximate sizes are arrived at an approximate cost for investment and O&M costs are worked out for various technology options for providing water supply, sanitation, roads and drains. Approximate rates for pipelines, water storage tanks, filtration units, ground water recharging structures are considered while preparing the line estimates based on the previous experience structures are considered while preparing the line estimates based on the previous experience. Hence, a near reasonable line estimate for capital cost and O & M cost can be arrived at so that the community can take an informal decision. After which a Preliminary Project Report (PPR) is prepared consisting of the executive summary, salient features, line estimates, capital cost and O&M cost for various technology options, schematic sketches and village map. The PPR will be presented to the community in a Gram Sabha, where various technology options will be discussed and the community will choose the most suitable options which are affordable to them (with respect to water supply and village sanitation). At the end of Gram Sabha the land required for the implementation of the scheme should also be identified and acquisition if necessary shall be completed before detailed scheme report is to done.

4.2. Format for Preparation of Preliminary Project Report

The various details that are to be collected in the preparation of a Preliminary Project Report (PPR) are broadly identified as follows:

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- 1) For MVS identification of villages, gram panchayats, group of villages to be covered under the project.
 - 2) Description of the area with reference to its location, terrain and accessibility.
 - 3) Socio-economic status, cultural activities, historic importance of the area.
 - 4) Present population of the area proposed to be covered in the project.
 - 5) Present status of water supply, sanitation condition. List of the problems deficiencies by inspection, local enquiry or studying the existing systems / records, if available.
 - 6) Land use in the area, master plan of the project area.
 - 7) Water requirement of projected population. Commercial and other non-domestic requirements, if any, adopting appropriate per capita demand.
 - 8) Type of existing roads need for improvement, type of traffic, width of roads, etc.
 - 9) Establish the need of project in the light of existing facility and future projected demands.
 - 10) Listing of the difficulties if any for implementation of the project and suggest remedies to overcome them considering the local conditions.
 - 11) Identification of project components like water source, improvements to existing one by augmentation or new one, collection, conveyance, treatment, storage distribution, etc. Adequacy of quantity and quality of water source. What are the components required for satisfactory service when project is completed.
 - 12) Preliminary cost of project (based on components of items), share of beneficiaries.
 - 13) Cost of operation and maintenance.
 - 14) Suggest the most economical scheme for beneficial implementation suitable for the project area with alternatives.
 - 15) Action plan for implementation of the project.
 - 16) Index plan to indicate the project area, existing facilities, proposed works and schematic diagram showing salient details of the project to be enclosed in the report.

4.3. Format for collecting data

- 1) Names of village in the scheme area (for MVS)
- 2) Name of gram panchayat
- 3) Name of the Mandal
- 4) Name of the District
- 5) Accessibility by road / rail
- 6) Present population (year)
- 7) Occupation of villagers
- 8) Whether covered under individual rural water supply scheme or mini water supply scheme or not
- 9) Source of present water supply, quantity and quality
- 10) Adequacy of water supply
- 11) Water supply service – through stand post / cisterns, house service connections
- 12) Hours of water supply – morning, afternoon, evening (or) continuous
- 13) House connections – metered or non-metered
- 14) Water charges – fixed flat rate / variable rates
- 15) Disinfection arrangement
- 16)

4.4. Details of existing Water Supply Source

Open well/tube well

- 1) Size
- 2) Total depth
- 3) Water column depth
 - a. During winter
 - b. During summer

Details of pump set

- 1) Capacity of pump
- 2) Type
- 3) Discharge
- 4) Head
- 5) Nos. installed

Pumping Main

- 1) Size
- 2) Length
- 3) Material of pipe
- 4) Class of pipe

Storage

- 1) Ground level
- 2) Capacity
- 3) Size
- 4) Material of construction

Overhead Tank

- 1) Capacity
- 2) Staging height
- 3) Pipe size inlet
- 4) Outlet
- 5) Overflow
- 6) Washout
- 7) Material of pipe

Distribution network

- 1) Pipe size
- 2) Length in each size
- 3) Material of pipe

Status of Existing Drains & Sanitation

- 1) Nature of drains - Kutcha / pucca / no drains
- 2) Size
- 3) Service condition
- 4) Storm water disposal
- 5) Type of drain - stone slab / precast slab
- 6) Sanitation facility (if available) – Community / Individual Toilets

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- 7) Mode of disposal of excreta
(Describe the present practice in brief)
 - 8) Status of existing roads
 - 9) Nature of roads - Mud / kutcha / Metalled / Asphalt/CC
 - 10) Width of roads
 - 11) Provision of storm water in design- considered/not considered

4.5. Format for Conceptual Design Report

- 1) Name of scheme
- 2) Names of villages covered under scheme
- 3) Accessibility
- 4) Terrain
- 5) Climatic conditions of the area
- 6) Socio-economic status
- 7) occupation of people
- 8) Cultural activities
- 9) Religion
- 10) Historic activities
- 11) Present population
- 12) Future population
- 13) Design period
- 14) Per capita water supply
- 15) Water supply for non-domestic requirements
- 16) Net water requirement (12x(14+15))
- 17) Account of losses in
 - a. Transmission
 - b. Treatment units
 - c. Distribution
 - d. Unaccounted water =
- 18) Gross water requirement (16+17)
- 19) Source of supply

Stream/river : (storage to be provided if non perennial)
 Storage Reservoir : (To meet 240 days demand or during low yield period of source)
 Irrigation canal : (provide storage equal to canal closure period)

- 20) Intake structure (to provide for drawl of water from surface waters)
 - a. Infiltration Wells / Intake Well
 - b. Infiltration Galleries (optional for streams with sufficient sand depth)
 - c. Intake Pipes
 - d. Intake Chamber
 - e. Jackwell with 2 floors, one for pipes galleries and another floor for Motors and panel boards.
 - f. Double Deck Bridge from Jackwell to Abutments of the river for conveyance of pipe lines & for accessing foot path for maintenance
 - g. Approach Earthen Embankment Road up to Abutments with revetment.

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- 21) Power lines & Transformer Yards for 24 hours continuous power supply (approximate cost 8-15 Lakhs per KM length of power lines) for Intake structures
- Distance in KM from nearest SUB STATION :
 - Type of power lines required : HT or LT
 - Transformers Yard size :
 - Capacity of Transformers including standby arrangements :
 - Type of Transformers :HT to HT , HT to LT or LT to LT
- 22) Raw water pumping machinery :To SS Tank
- Hours of pumping (for ultimate demand, Q) = 20 hrs.
 - Hours of pumping (For Prospective Demand) = suitably reduced.
 - Discharge at Duty point (for Ultimate demand) Q = LPM
 - Static Head (MWL at end - LWL of water source/jack well)= M
 - Head losses due to Friction = M
 - Other (minor) losses in Pipe lines 10% on Friction = M
 - (Suction + Delivery Losses, etc.) = 5 M
 - Total Head lift of pump set $H = M$
 - Combined Efficiency of pump sets : $\eta=70\%$ for VT 40% for submersible pump sets
 - Horse power = $(Q \times H) / (4500 \times \eta)$
- 23) Pumping Main from Intake structures to SS Tank
- Diameter of pipes : To be decided economically and Velocity of flow, Between 0.6 m/s to 2.0 m/s
 - Type of Pipes and details: To be decided economically and to suit the ground terrain of pipe line layout.
 - Length of pipe line: in M
- 24) Summer Storage Tank (Impounding reservoir ,large storage of water for summer periods/ in the absence of running water from streams)
- Location of SS Tank: may be an abunded tank /M.I.Tank canal feeding
 - Qty of water stored in SS Tank: in Mcft , Qty required for non running period of canal/stream , Qty required for 4 to 8 months period, +50% evaporation and percolation losses.
 - Dimensions of SS Tank, detailed grid levels, all required designs and drawings etc., details.
 - Cut-off trench, Revetment , weir length, bypass arrangements, fencing etc.,
 - Area required for SS Tank: in acres
 - Intake Chamber for collection of water for dead storage in SS Tank with gate valve arrangements.
 - Jackwell with 2 floors, one for pipes galleries and another floor for Motors and panel boards.
 - Double Deck Bridge from Jackwell to Abutments of the river for conveyance of pipe lines & for accessing foot path for maintenance.
 - Approach Earthen Embankment Road up to Abutments with revetment.
- 25) Power lines & Transformer Yards for 24 hours continuous power supply (approximate cost 8-15 Lakhs per KM length of power lines) for SS Tank.
- Distance in KM from nearest SUB STATION :

-
- b. Type of power lines required : HT or LT
 - c. Transformers Yard size :
 - d. Capacity of Transformers including standby arrangements :
 - e. Type of Transformers :HT to HT , HT to LT or LT to LT
- 26) Raw water pumping machinery : to WTP
- a. Hours of pumping (for ultimate demand, Q) = 20 hrs.
 - b. Hours of pumping (For Prospective Demand) = suitable reduced.
 - c. Discharge at Duty point (for Ultimate demand) Q = LPM
 - d. Static Head (MWL at end - LWL of water source/jack well) = M
 - e. Head losses Due to Friction = M
 - f. Other (minor) losses in Pipe lines 10% on Friction = M
 - g. (Suction + Delivery Losses, etc.) = 5 M
 - h. Total Head lift of pump set $H = M$
 - i. Combined Efficiency of pump sets : $\eta=70\%$ for VT 40% for submersible pump sets
 - j. Horse power = $(Q \times H) / (4500 \times \eta)$
- 27) Pumping Main from Jack well to WTP
- a. Diameter of pipes : To be decided economically and Velocity of flow,
Between 0.6 m/s to 2.0 m/s
 - b. Type of Pipes and details: To be decided economically and to suit the
ground terrain of pipe line layout.
 - c. Length of pipe line: in M
- 28) Water Treatment Plant :
- a. Name of the Location of WTP:
 - b. Capacity of (WTP) Filters:
 - c. Type of Filtration Plant: SS Filters or RS Filters
 - d. Brief details of units proposed:
 - e. Area required for arrangements of the Units in WTP:
- 29) Ground Level Storage Balancing Sump (GLBS)
- a. Capacity–2.5hours of incoming discharge or balancing capacity between
total outflow qty and total inflow qty in a day.
 - b. Size of Tank whether Circular or Rectangular
 - c. Free Board – 0.3 m
 - d. Sizes of inlet & overflow arrangements in outside chamber
 - e. Sizes of Scour Valve with, outside chamber arrangements
- 30) Clear Water Pumping Main from GLBS to ELBR
- a. Diameter of pipes : To be decided economically and Velocity of flow,
Between 0.6 m/s to 2.0 m/s
 - b. Type of Pipes and details: To be decided economically and to suit the
ground terrain of pipe line layout.
 - c. Length of pipe line: in M
- 31) Elevated Level Balancing Reservoir
- a. ELBR Capacity – 30 minutes of incoming flow, capacity adopted for higher staging
for stability of ELBR.
 - b. Staging height – Required to flow by gravity to all drawls points in the network for
Ultimate design discharge by 10% more.
 - c. Size of inlet : \leq incoming pipe line diameter but velocity < 2.0 m/s
-

- d. Size of outlet : \leq Outgoing pipe line diameter but velocity $< 1.5\text{m/s}$
- e. Size of scour : normally with $\leq 80\text{mm}$
- f. Size of overflow: normally with \leq outlet size.,
- g. Bell mouth pieces to be provided for all verticals.

32) Clear Water Pumping machinery for GLBS to ELBR

- a. Hours of pumping - 20 hrs.
- b. Hours of pumping (For Prospective Demand) = suitably reduced
- c. Discharge: For Ultimate Demand, suitable to outflow rate from ELBR, ie equals to System Capacity of Transmission lines from ELBR at LWL.
- d. Static Head (MWL at end - LWL of water storage/sump)= M
- e. Head losses due to Friction = M
- f. Other (minor) losses in Pipe lines 10% on Friction = M
- g. (Suction + Delivery Losses, etc.) = 3 M
- h. Total Head on pump set $H = M$
- i. Combined Efficiency of pump sets : $\eta=60\%$ for HSC, 40% for submersible pump sets
- j. Horse power = $(Q \times H) / (4500 \times \eta)$

33) Gravity Mains from ELBR to OHSR/sumps of habitations

- a. Diameter of pipes : To be decided economically and Velocity of flow, Between 0.6 m/s to 2.0 m/s , no bar for min. Dia.
- b. Type of Pipes and details: To be decided economically and to suit the ground terrain of pipe line layout.
- c. Length of pipe line: in M

34) Break Pressure Tanks (BPT)

- a. ELBR Capacity – 15-30minutes of incoming flow, capacity adopted for higher staging for stability of ELBR. Capacity can be increased to maintain the minimum velocity in further gravity transmission lines.
- b. Staging height – Required to flow by gravity to all drawls points in the network for Ultimate design discharge by 10% more.
- c. Size of inlet : \leq incoming pipe line diameter but velocity $< 2.0\text{ m/s}$
- d. Size of outlet : \leq Outgoing pipe line diameter but velocity $< 1.5\text{m/s}$
- e. Size of scour : normally with $\leq 80\text{mm}$
- f. Size of overflow: normally with \leq outlet size.,
- g. Bell mouth pieces to be provided for all verticals.

35) Gravity Mains from BPT to OHSRs/sumps of habitations

- a. Diameter of pipes : To be decided economically and Velocity of flow, Between 0.6 m/s to 2.0 m/s , NO BAR for min. Dia.
- b. Type of Pipes and details: To be decided economically and to suit the ground terrain of pipe line layout.
- c. Length of pipe line: in M

36) Intermediate Ground Level Storage Balancing Sump (IGLBS)

- a. Capacity–2.5hours of incoming discharge or balancing capacity between total outflow qty and total inflow qty in a day. If dedicated power supply not available within permissible distance (cost criteria between power connection charges

and the deference cost of sump, OHBR, pumping/main, further gravity transmission pipe lines), 24 hours demand is considered.

- b. Size of Tank whether Circular or Rectangular
- c. Free Board – 0.3 m
- d. Sizes of inlet & overflow arrangements in outside chamber
- e. Sizes of Scour Valve with, outside chamber arrangements

37) Clear Water Pumping Main from IGLBS to IELBR

- a. Diameter of pipes : To be decided economically and Velocity of flow, Between 0.6 m/s to 2.0 m/s , depends on pumping hours.
- b. Type of Pipes and details: To be decided economically and to suit the ground terrain of pipe line layout.
- c. Length of pipe line: in M

38) Clear Water Pumping machinery for IGLBS to IELBR and or to OHSRs independently nearby habitations.

- a. Hours of pumping - 20 hrs./6 Hours if sub-station far away.
- b. Hours of pumping (For Prospective Demand) = suitably reduced
- c. Discharge: For Ultimate Demand, suitable to outflow rate from ELBR, i.e. equals to System Capacity of Transmission lines from ELBR at LWL.
- d. Static Head (MWL at end - LWL of water storage/sump) = M
- e. Head losses Due to Friction = M
- f. Other (minor) losses in Pipe lines 10% on Friction = M
- g. (Suction + Delivery Losses, etc.) = 3 M
- h. Total Head on pump set

H = M

- i. Combined Efficiency of pump sets : $\eta=60\%$ for HSC, 40% for submersible pump sets
- j. Horse power = $(Q \times H) / (4500 \times \eta)$

39) Intermediate Elevated Balancing Reservoir (IELBR)

- a. IELBR Capacity – 15-30minutes of incoming flow, capacity adopted for higher staging for stability of ELBR. Capacity can be increased to maintain the minimum velocity in further gravity transmission lines.
- b. Staging height – Required to flow by gravity to all drawls points in the network for Ultimate design discharge by 10% more.
- c. Size of inlet : \leq incoming pipe line diameter but velocity < 2.0 m/s
- d. Size of outlet : \leq Outgoing pipe line diameter but velocity < 1.5 m/s
- e. Size of scour : normally with ≤ 80 mm
- f. Size of overflow: normally with \leq outlet size.,
- g. Bell mouth pieces to be provided for all verticals.

40) Gravity Mains from IELBR to OHSRs/sumps of habitations

- a. Diameter of pipes : To be decided economically and Velocity of flow, Between 0.6 m/s to 2.0 m/s , NO BAR for min. Dia.
- b. Type of Pipes and details: To be decided economically and to suit the ground terrain of pipe line layout.
- c. Length of pipe line: in M

41) Service Reservoirs (OHSRs) :

-
- a. OHSR/GLSR Capacity – one full day capacity adopted with required staging.
 - b. Staging height – Required to flow by gravity while 6m residual head maintained to all end points in the distribution network for Peak Ultimate design discharge.
 - c. Size of inlet : \leq incoming pipe line diameter but velocity < 2.0 m/s
 - d. Size of outlet : \leq Outgoing pipe line diameter but velocity < 1.5 m/s
 - e. Size of scour : normally with ≤ 80 mm
 - f. Size of overflow: normally with \leq outlet size.,
 - g. Bell mouth pieces to be provided for all verticals.
- 42) Distribution System: To be dealt independently, depends upon village population, power availability and social system of habitations and for satisfying the minimum velocity criteria $v \geq 0.6$ m/s (tandas, small village pop <500 , mandal head quarters, major Village, pilgrim centre, weekly market centre, etc.,)
- a. Design for peak factor: 12 to 3 for Rural habitations, very small to big rural habitations as per their social system of living.
 - b. Size of pipes : Depends on Q, Min. 50 mm for < 1000 Rural population , 65 mm for $< 30,000$ Rural population, 100mm for $< 50,000$ city population, 150mm for $> 50,000$ city population.
 - c. Length of pipe line & layout maps on TOPO sheets.
 - d. Material of pipe:
 - e. Appurtenances: includes, water meters.
 - f. Control valves – sizes: includes, pressure reducing valves
 - g. Public taps (one for 150 persons) :
 - h. House service connection -
- 43) Cost of components: (list the components and with their alternate cost)
- 44) Financial aspects
- a. Contribution by beneficiaries
 - b. Grant in aid by State / Central Govts.
- 45) Annual maintenance and repairs :
- 46) Annual instalment of loan repayment (in 20 year time):
- 47) Annual interest on loan:
- 48) Depreciation fund for replacement:
- 49) Total annual cost (45+46+47+48):
- 50) O & M cost per capita (49 \div population):
- 51) Capital cost per capita (43 \div population):
- 52) Cost of water per 1000 ltrs = $\frac{(50) \times 1000}{(\text{Population} \times \text{Per Capita} \times 365)}$.

4.6. Capital Cost and O & M Cost

TABLE:4.1

Capital cost

Sl. No.	Description	Rs.
1.	Source of supply works	
2.	Intake structures	
3.	Pumping main	
4.	Treatment units (optional)	
5.	Storage at ground level	
6.	Service Reservoirs	
7.	Pumping machinery from GL tank to Elevated tank	
8.	Distribution system	
9.	Electrical works	
10.	Land acquisition	
11.	Other unforeseen item of works.	
	Total	

O & M Cost

Sl. No.	Description	Rs.
1.	Annual maintenance and repairs Civil works at 1 % Electrical & Mechanical at 5%	
2.	Annual salary of operating staff	
3.	Annual energy charges	
4.	Annual chemical charges	
5.	Annual depreciation fund (@0.2 % for civil works and@ 2 % for Mechanical and Electrical works)	
	Total	

Per Capita Cost (for ultimate population)

- a. Capital cost -
- b. O & M cost -

CHAPTER – 5

5. DETAILED PROJECT REPORT

This chapter contains the methodology adopted for detailed engineering for a rural water supply scheme. Field survey, design calculations, detailed plans and estimates etc are described. The preparation of detailed project report (DPR) commences only after approval of the Preliminary Project Report and therefore the designs and estimates will be prepared for the chosen technology option only.

The various components for different rural water supply schemes based on surface source and groundwater source are shown in the table 5.1. The technology option is to be finalized in consultation with the community before starting of DPR. The schematic diagram of water supply scheme is shown at Fig.5.1.

TABLE: 5.1

S.No	Technology Option	Components
1	Bore well with Hand Pump	100mm/150mm Bore well, Mark III Hand pump
2	MPWS Scheme	Bore well/Infiltration well, Pumpset, GLSR, Pumping main, Taps
3	PWS Scheme/SVS	Source, Pumpset, Pumping main, OHSR, Distribution system, Disinfection, Public stand posts, House connections , Pump room
4	CPWS Scheme/MVS	Source, intake well, Raw water pumping main, Treatment plant, Clear water sump , OHBR, OHSRs , Pump rooms , Pump sets, Disinfection , Staff quarters , Distribution system.

5.1. Surveys

The following surveys are required for preparing DPR

Sanitary Surveys

In these days of industrialization and urbanization, the admission of human excrement and industrial wastes to existing storm drains seems to offer a cheap and ready way of this hygiene and aesthetic dilemma. Most of the early constructed sewers and industrial drains terminate into the nearby streams, lakes and rivers without undergoing any treatment. With this the natural sources of water are overtaxed. The greatest danger thus lies in contamination from human sources. The detailed sanitary survey of the area when the sources of water are selected is, therefore, of prime importance requiring the critical sanitary of the sources and its surroundings. The sanitary survey should cover the entire catchments area and in case of river as a source, a distance of 10 km upstream and 2 km down stream from the point of proposed intake.

Field Survey

The next step in detailed engineering is a field survey to find the levels at source, at OHSR/GLSR and along the road network. In addition, lengths and alignment (bends) shall be recorded. If any village map is readily available it will be up dated. Usually methods of survey applicable for villages are

chain and compass survey, level survey, and plane tabling and total station survey. Field survey and leveling work to be carried out is connected with the development of sources, silting of dams, catchments survey, silting of various components of treatment units, location of storage reservoirs with their capacities and elevations, alignments and longitudinal sections of pumping main and distribution systems. A topographical map should indicate the location of all houses, schools, markets, hospitals, health centers, important public buildings and industries which would require special consideration from the point of view of water system.

Total Station Survey System (TSSS)

It is a modern method, which provides accurate and fast field information on levels, distances, angles and landmarks. The TSSS is a system that includes an electronic angle measurement, electronic distance measuring instrument (EDMI), and an electronic data collecting system. The system also includes tripods, prisms, targets and prism poles. The TSSS system is used to perform the conventional survey methods of traverse, network, resection, multiple ties, and trigonometric leveling. This will be useful for planning all future village developmental activities. Survey control points established with TSSS can be linked with Geo-coordinates and the data obtained is directly transferred to a personal computer and digital maps are generated. This process will yield highly accurate survey field data. Survey using GPS and Total station ensures Millimeter accuracy compared to the traditional method of survey, Total Station survey results in lot of savings in terms of time, money and man-days while ensuring more accuracy and lending itself to easy access, retrieval and utilization of data.

- The levels required shall normally be co-related to Mean Sea Level. Permanent as well as temporary benchmarks shall be established at prominent places within the village for future requirements.
- Detailed 'L' section survey should be carried out along the existing roads for all pipelines and distribution system network. Levels shall normally be taken at 15 m intervals. If necessary, additional levels may be taken at road junctions, bends or peaks and valleys. Net levels (Grid levels) are taken usually at 5 m intervals for block survey of OHSR / GLSR sites, treatment plant sites, pumping stations and intake structures.
- The trial pits for pipelines shall be of size 1m x 1m and for a depth of about 1m to note the nature of soil preferably at 500 m intervals.
- However, trial pits for other structures shall be taken to a depth of up to 2m to note the nature of soil and subsoil water if any. Bearing capacity of the soil is determined by SPT method and soil samples collected and tested in laboratory to co-relate the results obtained in the field. For exceptional cases such as very loose soils or filled up soils, detailed soil analysis may be required.

Geological and rain fall data

A thorough study of geological and rain fall data pertaining to the area should be care fully conducted. This information has an important bearing on the decision-making regarding the particular source of water. Local people in this regard are contacted for guidance .The survey of existing wells and bore wells should be conducted. The amount of water drawn and the rate of recovery of the water table are indicative of the capacity of water bearing stratum.

Detailed Designs factors

- **Population forecast:**-The Population fore cast is made as per the procedure explained in the chapter 2, considering the type of village.
- **Per capita demand:** - The per Capita demand is taken for design purposes as per the procedure explained in chapter and quantity of water is to be calculated for prospective and ultimate designs.
- **Design period;** - The design period for different components is to be finalized.
- **Quality of water of available source and yield:** - The quality of water source is to be assessed for type of treatment purposes, and the yield of the source is also assessed. If one yield is not sufficient to the requirement, then alternate yield is to be selected.

5.2. Selection of Source

The origin of all sources of water is rainfall. Water can be collected as it falls as rain before it reaches ground; or as surface water as it flows over the ground; or it can be collected in ponds/lakes; or as groundwater as it percolates down to aquifers. However, in Andhra Pradesh State the main sources of water for irrigation and drinking purposes is ground water and surface water from irrigation canals. Depending upon the availability of potable water in the region the source of water supply is selected as surface or ground water.

Ground water based schemes

Ground water based supply schemes shall have generally following components.

- **Tube Wells:**

Underground water, which is abundantly available in most districts of Andhra Pradesh, is tapped through installing Tube Wells. Tube Wells shall be drilled in accordance with Indian Standard IS: 2800 (Part – I) -1979, developed in accordance with IS: 11189-1985 with latest amendments and tested in accordance with IS: 2800 (Part-II) – 1979, with latest amendments.

General Requirements and guidelines

Diameter:	150mm or 200mm
Depth:	as recommended by the Geologist
Casing Pipe:	MS casing pipe / PVC casing pipe up to the depth of loose soils until hard strata is met.
Pump set:	Submersible pump set of adequate capacity with due consideration to the safe yield of the bore well.
Pipes:	GI pipes / HDPE pipes

- **Dug Wells:**

Plan:	Preferable circular in plan located as per ground water availability
Diameter:	4m, 5m, 6m, 8m and 10m (as per the demand)
Depth:	8m – 15m depending on water bearing stratum.
Steening:	RCC walls with weep holes
Platform:	3m all round the well 0.45m above ground level
Parapet:	1.2m above platform level
Filter:	well bottom to be provided with 0.6m thick invert filter media using 40mm to 12mm clean stone media.

Surface water Sources

The following are the base surface water sources.

- Canals
- Rivers
- Ponds / lakes

Flow and Location : Preferably perennial flow and location to be safe and secure.

Inlet works : Inlet chamber with screeners, inlet below lowest summer water level.

Jack well : 4-6m dia depending upon the capacity, sufficient for pump house, pump sets, valves, panels etc.

Physical, chemical and bacteriological examination

Physical, chemical and bacteriological analysis must be made during both dry and rainy periods, for the results may vary considerably. A number of samples should be collected for analysis. A thorough study of water source would therefore reveal the type of treatment needed to handle particular type of raw water available.

5.3. Design of intake/Raw water collection well

When surface water is decided to be the technology option, it calls for specific structures for the drawl and transmission called intake well or raw water collection well. These are the structures placed in a surface water source to permit the withdrawal of water from the source. These are essentially used in rivers etc., where wide fluctuations in water level are expected.

Location and Design Considerations:

- It shall be located such that the raw water can be withdrawn continuously over the year.
- It shall be nearer to the raw water sump.
- The location shall be free from the water currents and swirls.
- The entrance of large objects shall be prevented by screens.
- The capacity of the conduit and depth of suction well should be such that the intake ports to the suction pipes do not draw air. A velocity of 60-90 cm/sec will give satisfactory performance.
- The intake conduit shall be laid in a continuous rising or falling grade to avoid accumulation of gas or air.
- Normally, the size of the well shall be equal to 30 minutes of pumping capacity
- Jack well with pump house is generally constructed with R.C.C. as per site condition. The floor level is kept above the high flood level to avoid submergence of pumps during floods. The floor area shall be enough to provide space for placement of pump motors, control panel, delivery piping and valves.
- Proper access shall be provided to the jack well for transport of pumps, etc.

Schematic diagrams of different intake and raw water collection wells are shown in the figures 5.2, 5.3, 5.4 and 5.5.

In tanks and canals where the fluctuation in water level is not appreciable the raw water can be directly flow into the sump of jack well through Pumping main

5.4. Impounding Reservoir/Summer Storage Tank

- Storage has to be provided for non-monsoon period plus allowance for silt, seepage, dead storage, and evaporation.
- It is recommended to explore possibility of using an existing tank to minimize the high cost of construction of impounding reservoir.
- If supply has to be drawn from existing tank or canal it may be drawn from live storage and also have facility for intake works to draw water from dead storage for drinking water supply system.
- Intake well in SS tank is to be located where dead storage is maximum
- Layer wise compaction of soils is to be ensured for the bund.Design for capacity required:

The summer storage tanks shall be provided for storing the requirement during the canal closer period. Canal closure periods vary from 3 to 9 months. Generally for closure periods up to 4 months, a minimum of 50% extra is provided in the storage towards percolation and evaporation losses. The pan evaporation Data as per T. Hanumantha Rao's manual shall be used, for assessing the evaporation losses of a region for the canal closure period.

Case Study:

Case 1: Canal Closure period up to 4 months.

Storage Capacity

Population as per 2001 census	:	100
Considering 2009 as the commissioning year		
Present Population = $100(1+1/100)^{(2009-2001)}$	=	108
(Adopting 1% growth rate of population)		
The SS Tanks are designed for ultimate population		
Ultimate Population = $108(1+1/100)^{20}$	=	132
Raw Water Demand	=	50 LPCD
Canal Closure Period	=	120 days
Ultimate Daily Demand	=	$132 \times 50 = 6600$ Ltrs per day
Storage Required for Canal Closure Period	=	$6600 \times 120 = 792000$ Ltrs
	or	792 cum
Add 50% for Evaporation and Percolation Losses	=	396 cum
Storage Capacity Required = 792+396	=	1188 cum.

Discharge through Pumping Main

The discharge through pumping main from canal to SS tank shall be the summer storage discharge which is to be drawn during canal operation Period and the daily discharge required for the scheme.

Storage for Canal Closure Period	=	1188000 L
Canal Operation Period = 365 – 120	=	245 days
Discharge per day for Summer Storage	=	4849 L
For 12 hours operation, discharge for summer storage	=	$4849/(12 \times 60) = 6.73$ LPM
Ultimate daily demand	=	6600 L
Daily Discharge per day for 12 hours of operation	=	$6600/(12 \times 60) = 9.17$ LPM
Total Discharge through pipe	=	$6.73 + 9.16 = 15.89$ LPM

Case 2: Canal Closure Period more than 4 months

Population as per 2001 Census	=	100
Considering 2009 as the commissioning year		
Present Population = $100(1+1/100)^{(2009-2001)}$	=	108
The SS Tanks are designed for Ultimate Population		
Ultimate Population = $108(1+1/100)^{20}$	=	132
Raw Water Demand	=	50 LPCD
Canal Closure Period	=	240 days
Ultimate Daily Demand = 132×50	=	6600 Ltrs Per day
Storage Required for Canal Closure Period	=	$6600 \times 240 = 1584000$ Ltrs
	or	1584 cum.

Let the depth of water in SS Tank be 4.0m. Consider TBP HLC in Kurnool District as the source and the canal closure period from September to May.

As per pan Evaporation Data, Cumulative Loss due to evaporation losses = 1593.2 mm **or** 1.59m

Percentage for Evaporation Losses	=	$(4-1.59) / 4 \times 100 = 60.25\%$
For Percolation Losses, the provision required is 15% to 20%		
Total Provision for percolation and Evaporation Losses	=	$60.25+20 = 80.25\%$
Add 80% for Evaporation and Percolation Losses	=	1271.16 cum
Storage Capacity Required	=	$1584+1271.16 = 2855.16$ cum

Discharge through Pumping Main

The discharge through pumping main from canal to SS Tank shall be the summer storage discharge which is to be drawn during canal operation period and the daily discharge required for the scheme.

Storage for Canal Closure Period	=	2855160 Ltrs.
Canal Operation Period = $365 - 240$	=	125 days
Discharge per day for Summer Storage	=	22841.28 Ltrs. per day
For 12 hours of operation, LPM discharge for summer storage=	=	$22841.28 / (12 \times 60) = 31.72$
Ultimate Daily Demand	=	6600 Ltrs. per day
Discharge per day for 12 hours operation	=	$6600 / (12 \times 60) = 9.17$ LPM
Total Discharge through Pipe	=	$31.72 + 9.17 = 40.89$ LPM

Note: Diameter of pipe for pumping main can be obtained by using the formula $0.76(Ipm)^{0.46}$.
The class and type of pipe can be decided by considering frictional losses and other losses due to transmission, length of pipe, water hammer and static head available.

b. Bund formation**(i) Reconnaissance**

The site selected for SS tank should be:

1. Nearer to the Canal to minimize the raw water pumping length
2. Should have adequate B.C soil depth to minimize the seepage losses (minimum of 60 cms)
3. Rocky portions having faulty zones should be avoided.
4. Barrow areas should be nearer to the site with required quantity of soil available for formation of bunds

(ii) Field investigations/survey

Before grounding the work, trial pits have to be taken at the site at regular intervals to know the depth of BC soil available. Representative soil samples in required quantities shall be collected from the trial pits at site and barrow areas, duly identifying the trial pit numbers and the level at which the soil samples are collected. Undisturbed soil samples shall be collected in accordance with the procedures laid down in IS:2132 – 1972 and are tested in the

laboratory for their suitability and classification. The following tests are to be conducted to assess their suitability for embankment.

1. Grain Size analysis
2. Atterberg's limits
3. Shrinkage limit
4. Optimum moisture content
5. Proctor's Density
6. Shear strength at optimum moisture content and at 100% saturation
7. Permeability at proctor's density.

The soil classification should be done as per IS: 1498 – 1970.

A survey has to be conducted and block levels at 30m interval have to be plotted to know the topographic features of the site. Based on the topographic features the available storage capacity at site can be calculated by plotting the contours at 0.10 to 0.50m interval. The storage capacity required is calculated by deducting the balance capacity available as per contour capacity calculations after making a provision for dead storage (10 to 20 percent); from the design capacity. The capacity provided can also be checked by Block area method as per the Proforma given under. In this method the area between centerline of bund is identified. Average of 4 corners block levels (block levels formed by 30m interval levels) in a block is taken. The water column height in each block is calculated and added to get actual storage provided.

Capacity calculation by block area method

c. Capacity calculations of S.S tank

Data
Off Take Level
M.W.L
T.B.L
Top Width
Side Slope
Free Board

Block No.	Avg. GL	Length Breadth		Block Area	Depth Above OTL	Volume Above	Depth below OTL	Volume below	Length of bund	Volume of bund above OTL	Volume of bund below OTL
		in mt.	in. mt	(sq.m)	in mt.	Off take	OTL	OTL	in mt.		
1	2	3	4	5	6	7	8	9	10	11	12

5.5. Sumps

Raw water sump

It acts as an equalizing reservoir which enables the filters to work at a constant rate. Generally a circular sump is to be designed. The raw water sump is provided for collection of raw water from intake well. Generally a circular sump is to be designed. Water will be pumped from raw water sump to treatment units.

Clear water sump

Sump is an underground tank constructed in RCC for storage of filtered water. It acts as an equalizing reservoir which enables the filters to work at a constant rate. Generally a circular sump is to be designed. The capacity of clear water sump depends on factors as number of filter bed units and number of hours the filter bed operates daily. If the filter bed works for 24 hours, then less capacity of sump is required. In case clear water sump is to supply water by gravity to distribution system, then if storage of distribution is sufficient to take care of peak requirement then less capacity of sump is required. If storage of distribution is not ample, then higher capacity of sump is to be taken up. In general 150 minutes capacity of sump is to be provided. In case of pumping is required from clear water sump to the OHSR/OHBR the capacity of sump depends upon the period for which pump works.

5.5.1. Transmission lines

Conveyance of water may be by gravity flow and / or pressure flow. Pipe lines used for transmission of water, normally follow the profile of the ground surface closely. Gravity pipelines have to be laid below the hydraulic gradient. RCC, Prestressed concrete, HDPE, AC, DI, CI, MS, GI and GRP pipes are used for pressure lines i.e. pumping/raising mains. HDPE/PVC/pre Stressed Pipes are normally used for gravity mains in rural water supply schemes. MS/CI/GI Pipes shall be used at all road crossings and in hard rocky strata regions.

Modified Hazen Williams Formula

The Modified Hazen Williams formula is used, for estimation of velocity, discharge and for loss of head due to friction which derived from Darcy-Weisbach formulae and Colebrook-White equations for coefficient of friction.

$$V = 3.83 C_R d^{0.6575} (gS)^{0.5525} / \nu^{0.105}$$

Where

C_R = Co-efficient of roughness

d = pipe diameter

g = acceleration due to gravity

s = friction slope

ν = viscosity of liquid

For circular conduits, V_{20}^0 for water = $10^{-6} \text{ m}^2/\text{s}$ and $g = 9.81 \text{ m/s}^2$

The Modified Hazen Williams formula derived as

$$V = 143.534 C_R r^{0.6575} S^{0.5525}$$
$$h = [L (Q/C_R)^{1.81}] / 994.62 D^{4.81}$$

in which,

V = Velocity of flow in m/s;

C_R = Pipe roughness coefficient, (1 for smooth pipes; <1 for rough pipes);

r = hydraulic radius in m;

s = friction slope;

D = internal diameter of pipe in m;

h = friction head loss in m;

L = length of pipe in m; and

Q = flow in pipe in m^3/s .

The value of Modified Hazen Williams co-efficient 'C_R' for different pipe materials and the value adopted for design purposes are given in Table 5.2.

TABLE 5.2

Pipe Material	Recommended value for	
	New Pipes	Design Purposes
AC, RCC, PSC, HDPE, PVC, GRP, BWSC, SGSW, in lined DI/CI/MS & All New pipes	1.0	1.0
DI/CI/MS	1.0	0.85
GI	0.87	0.74

Resistance due to specials and appurtenances

In pipelines there will be several transitions and appurtenances, which will add to the loss of head in addition to friction loss. These are normally expressed as velocity heads i.e. $KV^2 / 2g$

Where

V = Average velocity in a pipe of corresponding diameter in m/s

g = Acceleration due to gravity in m/s²

K = A specific resistance co-efficient for the specials of appurtenance

The values of K to be adopted for different fittings are given in the manual on water supply and treatment published by CPHEEO. However, in a rural water supply system it is recommended to calculate the head loss due to specials and appurtenances at 10% of frictional losses in pipeline.

However for short length segments the following % of losses over friction for account of other losses due to the specials and appurtenances are observed in the RWS field works.

<u>Pipe line segment</u>	<u>% on Frictional losses</u>
Length ≤ 50m	40%
Length ≤ 100m	30%
Length ≤ 150m	20%
Length ≤ 200m	15%

Co-efficient of roughness

The value of Hazen Williams co-efficient 'C' for different pipe materials and the value adopted for design purposes are given in Table 5.3.

TABLE 5.3

Conduit Material	Recommended value for	
	New Pipes	Design Purposes
Plastic Pipes (PVC)	150	145
Cast Iron, Ductile Iron and Mild Steel Pipes of dia. Up to 500 mm	130	110

Resistance due to specials and appurtenances

In pipelines there will be several transitions and appurtenances, which will add to the loss of head in addition to friction loss. These are normally expressed as velocity heads i.e.

$$K V^2 / 2g$$

Where

V = Average velocity in a pipe of corresponding diameter in m/s

G = Acceleration due to gravity in m/s^2

K = A specific resistance co-efficient for the specials of appurtenance

The values of K to be adopted for different fittings are given in the manual on water supply and treatment published by CPHEEO. However, in a rural water supply system it is recommended to calculate the head loss due to specials and appurtenances at 10% of head losses in pipeline.

5.6. Water Hammer

An understanding of the physical picture of water hammer phenomenon is of vital importance in dealing with the particular piping system under design. Water hammer requires consideration because it can damage the pipe and piping equipments.

Any sudden change in the flow velocity or pressure in a liquid line will produce hydraulic shock (water hammer). It is like a long, rigid spring; being stretched at a uniform speed is suddenly released. A pressure wave would travel back along the spring as it compressed at the point of stoppage.

Causes of Water Hammer and remedial measures: Surges or transient pressures are created in pipe lines as a result of change in steady State velocity of flow. This undesirable change in the velocity is because of

- Stoppage of pumps due to power failure
- Sudden closure of valve and
- Pulsation problem due to hydraulic ram and reciprocating pump.
- Apart from above, certain deliberate change in the velocity is brought about when the pumps are started or switched off.

It shall be borne in mind that the changes in the velocity whether deliberate or accidental are likely to create surges in the piping system. However, while making deliberate changes, one can readily take precautions to reduce the magnitude of surges, i.e. by closing the delivery sluice valves before stopping the pumps or the throttling of valve while starting them. But accidental changes catch the operator off guard and before he can do anything the surges are already developed and probably had their toll.

When a sluice valve in a pipeline is closed, the velocity of water column behind it is retarded and its momentum is destroyed. This situation results in thrust on the sluice valve and an additional pressure on the pipe wall behind. If the rupture occurs, it may take place near the valve simply because it acts there first otherwise the shock pressure is not concentrated at the valve. The valve closure period should be slowed down to take the larger period than the critical time of closure. The first 80% of the valve can be closed as quickly as possible but the last 20%, which is effective in shutting off approximately 80% of flow, should be closed as slowly as possible. Bypasses will help in closing or opening of large valves and should be closed last and this helps in reducing water hammer effect.

The pump set is shut off only after the delivery valve at the outlet of the pump is closed gradually so as to prevent the velocity rise in the pumping main. However, sudden power failure causes the sudden stoppage of pump set. Such sudden stoppage of pumps prevents the forward flow of water, which creates a separation of water column. Hence the water column ahead of the pump set rushes towards the pump set (with a reversal direction) and velocity increases by several times causing water hammer. This pressure rise or water hammer results in a series of shocks, sounding like hammer blows, which may be of sufficient magnitude to rupture the pipe.

The pressure due to water hammer depends on the elastic properties of the pipe material.

$$H_{\max} = C V / g$$

$$C = \frac{1425.000}{\sqrt{1 + Kd/Et}}$$

Where

H_{\max} = Maximum Water hammer head over the working pressure in m.

C = Velocity of pressure wave travel m/sec.

g = acceleration due to gravity in m/sec^2 ($9.81/\text{ms}^2$)

V = normal velocity in the pipeline before sudden closure in m/sec.

K = Bulk modulus of water ($2.07 \times 10^8 \text{ Kg/sqm}$)

d = Inner diameter of pipe in m

t = wall thickness of pipe in m

E = modulus of elasticity of pipe material

For D.I Pipes = $1.70 \times 10^{10} \text{ Kg/sq.m}$

For PVC = $3.00 \times 10^8 \text{ Kg/sq.m}$

For C.I. Pipes = $7.50 \times 10^9 \text{ Kg/sq.m}$

For HDPE Pipes = $9.00 \times 10^7 \text{ Kg/sq.m}$

For AC pipes = $3.00 \times 10^9 \text{ Kg/sq.m}$

For PSC pipes = $3.50 \times 10^9 \text{ Kg/sq.m}$

For WI pipes = $1.80 \times 10^{10} \text{ Kg/sq.m}$

For RCC pipes = $3.10 \times 10^9 \text{ Kg/sq.m}$

For steel pipes = $2.10 \times 10^{10} \text{ Kg/sq.m}$

For BWSC pipes = $1.0 - 1.5 \times 10^{10} \text{ Kg/sq.m}$

For GRP pipes = $1.0 - 2.0 \times 10^9 \text{ Kg/sq.m}$

The actual water hammer head can be calculated and added to the working pressure to arrive at the class of the pipe which shall be able to withstand the total head on account of water hammer plus the working head (allowable internal pressure of pipe lines can be increased for shock loads considerations as per the codal provisions for various type of pipes). Since water hammer head is a function of velocity, choosing a higher diameter pipeline reduces the velocity and hence reduces the water hammer head. However, cost effect has to be studied for choosing higher diameter pipe to minimize water hammer head or changing the pipe material or increasing the pressure class of pipe to withstand the water hammer head.

➤ Special Devices for Control of Water Hammer

The philosophy is

- (i) to minimize the length of returning water column causing water hammer
- (ii) to dissipate energy of the water column length by air cushion valve and
- (iii) to provide quick operating pressure relief valve to relieve any rise in pressures in critical zones.

These objectives are achieved by the following three valves.

- **Zero Velocity Valve**

The principle behind the design of this valve is to arrest the forward moving water column at zero momentum i.e. when its velocity is zero and before any return velocity is established.

With sudden stoppage of pumps the forward velocity of water column goes on decreasing due to friction and gravity. When the forward velocity becomes less than 25% of the maximum, the flap starts closing at the same rate as the velocity of water. The flap comes to the fully closed position when forward velocity approaches zero magnitude, water column on the upstream side of the valve is thus prevented from acquiring a reverse velocity and taking part in creating surge pressures. The bypass valve maintains balanced pressure on the disc and also avoids vacuum on the downstream side of valve if that column experiences certain reversal.

The main advantages of zero velocity valves are:

- (i) Controlled closing characteristics; and
- (ii) Low loss of head due to streamlined design.

- **Air Cushion Valve**

The principle of this valve is to allow large quantities of air in the pumping main during separation, entrap the air, compress it with the returning air column and expel the air under controlled pressure so as to dissipate the energy of the returning water column. An effective air cushion is thus provided.

The valve is mounted on Tee joint on the rising main at locations where water column separation is likely. The valve has a spring loaded air inlet port, an outlet normally closed by a float, spring loaded outlet poppet valve and an adjustable needle valve control orifice.

When there is sudden stoppage of pump due to power failure, partial vacuum is created in the main. With differential pressure, the spring loaded port opens and admits outside air into the main. When the pressure in the main becomes near atmospheric, the inlet valve closes under spring pressure. The entrapped air is then compressed by the returning water column till the proper valve opens. With float in dropped position, the air is expelled through poppet valve and controlled orifice under predetermined pressure thus dissipating the energy of the returning water column.

- **Opposed Poppet Valve**

As the name implies, the valve has two poppets of slightly different areas mounted on the same stem. The actual load on the stem is thus the difference in loads on the two poppets and is thus light. A weak spring is therefore, able to keep the valve closed under normal working pressure. If pressure in the water main increases beyond a certain limit, the increase in differential pressure overcomes the

holding pressure of the spring, opens the valve and allows water to discharge through both the poppets.

On account of the light spring the valve is able to open quickly and thus reduce the peak surge pressure to the desired limit.

5.7. Economical size of pumping main

In water supply projects, problem relating to the provision of long lengths of pumping mains to convey water are required to be solved. The size of the pipe to be provided is to be determined based on the initial capital cost of the installation and that of the operation. A pipe smaller than the required size may be adequate for delivering the water with less capital expenditure but the cost of bigger pumps and higher electrical / fuel charges to overcome higher friction will increase inversely with the size of pipe provided. These operation charges will be annual charges throughout the design period. Therefore, it will be seen for a particular set of conditions of flow, length of pipe, cost of pumping sets, cost of energy/fuel charges and the cost of pipe, it will prove most economical in the long run, taking into consideration both initial capital investment and running charges over a period which is usually the design period. The most economical size of the pumping main will therefore depend upon the proper analysis of the following factors:

For a given discharge, if smaller diameter of the pipes is selected the velocity of flow increases. However the increased velocity results in higher frictional loss and hence increases total pumping head, which requires increased HP of the pump. This leads to higher pumping cost and may offset the reduction in initial cost due to the smaller diameter pipe. Normally, the combined effect is a net increase in cost. On the other hand if too large a diameter of the pipe is used the cost of pumping will be less, but the initial investment in cost of pipeline and pumps has an annuity, which depends on the rate of interest and period of repayment of loan taken for capital investment. The annual operating cost of the pumps will vary depending on HP/KW of pumps (depend on size of pipeline). For the most economical condition we must choose such a pipe size, whose annuity due to initial cost together with the annual pumping cost will make the total annual expenditure minimum. The size of such a pipe is called economic size of the pipe. The optimum velocity for most economical sizes of pipes is likely to be about 1 meter /second.

The most economical size for conveyance shall be based on proper analysis of the following factors.

- The period of design considered or period of loan repayment
- Different pipe sizes against different hydraulic slopes
- Different pipe materials, which can be used for the purpose and their relative costs as laid in position.
- The duty, capacity and installed cost of pumps sets required against the corresponding sizes of pipelines under consideration.
- The recurring costs on Energy charges for running pump sets, Staff for operation of the pump sets, Cost of repairs and renewals of pump sets, and cost of miscellaneous consumable stores
- While selecting the class of the pipe higher of the following shall be considered, twice the working pressure at the top of the bore well and Working pressure at the top of the bore well, water hammer pressure.

Normally the pipe size required to give a velocity of 0.9 m/sec for a given discharge is worked out and the nearest commercially available size of pipe is selected. In addition two sizes of pipes above

and below the selected size are chosen for design purpose. This is done to obtain the size of the pipe, which together with the pumping cost will make the total annual expenditure minimum. In addition, the class of the pipe thus selected shall also be able to withstand the pressure due to water hammer effects plus the static head. The input data required are:

- Discharge of the pump – based on the safe yield of the bore well (lps)
- Hazen Williams Constant “C” for pipe material
- Total Length of the pipe from source to the OHBR
- Suction Head (for submersible pump it is 0 mt)
- Delivery Head
- Residual Head (Assume 6.0 mt)
- Reduced level of the Pump Set
(RL of Ground at Bore Well Point - Pump Set Level) (m)
- Reduced level of the Bore Level = RL of ground at Bore well point (m)
- Full Supply Level (FSL) = Ground RL + Staging Height + Water Depth
- Unit cost of pipes
- Unit rate of power

Keeping in mind the cost of pipe and water hammer pressure a suitable economical section is selected. (See Annexure III for Design)

5.8. Pipe Lines

Pipelines are major investments in water supply projects and as such constitute a major part of the assets of water authorities. Pipes represent a large proportion of the capital invested in water supply undertakings and therefore are of particular importance. Therefore pipe materials shall have to be judiciously selected not only from the point of view of durability, life and over all cost which includes, besides the pipe cost, the installation and maintenance costs necessary to ensure the required function and performance of the pipelines throughout its designed life time.

1. Gravity Pipelines
2. Pressure Pipelines

Gravity pipelines are those in which the water flows under the action of gravity. These pipelines cannot go up and down hills and valleys as per the available topography. In Pressure pipelines, water flows under pressure above the atmospheric pressure. The pressure pipes can follow natural available ground surface and can freely go up and down hills and valleys.

The structural design of the pressure pipes should be carried out, so as to enable them to withstand the various forces likely to come on them, such as

- Internal pressure of water including water hammer pressure to be resisted by using materials strong in tension.
- Pressure due to external loads in the form of backfill and traffic load to be resisted by materials strong in compression.
- Longitudinal temperature stresses created when pipes are laid above ground to be resisted by providing expansion joints.
- Longitudinal stresses created due to unbalanced pressure at bends, or at the points of change of cross section – to be resisted by holding the pipe firmly by anchoring it in massive blocks of concrete or stone masonry.

The various types of Pressure pipes are

- a) Ductile Iron (D.I) Pipes
- b) Cast Iron (C I) Pipes
- c) Mild Steel (M.S) Pipes
- d) R.C.C.Pipes, Prestressed Concrete Pipes.
- e) Asbestos Cement (A.C) Pipes.
- f) Poly Vinyl Chlorine (PVC) Pipes
- g) High Density Poly Ethylene (HDPE) Pipes.
- h) GRP Pipes.

The various types of Gravity Pipes are

- a) R.C.C.Pipes
- b) Prestressed Concrete Pipes.
- c) Asbestos Cement (A.C) Pipes.
- d) Poly Vinyl Chlorine (PVC) Pipes
- e) High Density Poly Ethylene (HDPE) Pipes

Selection of pipe materials must be based on the following considerations:

- The initial carrying capacity of the pipe and its reduction with use, defined, for example, by the Hazen-Williams coefficient C. Values of C vary for different conduit materials and their relative deterioration in service. They vary with size and shape to some extent.
- The strength of the pipe as measured by its ability to resist internal pressures and external loads.
- The life and durability of pipe as determined by the resistance to corrosion; to erosion, disintegration and to cracking .
- The ease of difficulty of transportation, handling and laying and jointing under different conditions of topography, geology and other prevailing local conditions.
- The safety, economy and availability of manufactured sizes of pipes and specials.
- The availability of skilled personnel in construction and commissioning of pipelines.
- The ease of operations and maintenance.

The life and durability of the pipe depends on several factors including inherent strength of the pipe material, the manufacturing process along with quality control, handling, transportation, laying and jointing of the pipeline, surrounding soil conditions and quality of water. Normally, the design period of pipelines is considered as 30 years. Where the pipelines have been manufactured properly as per specification, designed and installed with adequate quality control and strict supervision, some of them have been lasted more than the designed life provided the quality of water is non-corrosive. However, pipeline failures for various pipe materials even before the expiry of the designed life have been reported probably due to lack of rigid quality control during manufacture and installation, improper design presence of corrosive waters, corrosive soil environment, improper bedding and other relevant factors. Lined metallic pipelines are expected to last beyond the normal designed life of 30 years. However, the relative age of such pipelines depends on the thickness and quality of lining available for corrosion. The cost of the pipe material and its durability or design life are the major governing factors in the selection of the pipe material. The pipeline may have very long life but may also be relatively expensive in terms of capital and recurring costs and, therefore, it is very necessary to carryout a detailed economic analysis before selecting a pipe material. The metallic pipes are being provided with internal lining either with cement mortar or epoxy so as to reduce corrosion, increase

smoothness and prolong the life. Underground metallic pipelines may require protection against external corrosion depending on the soil environment and corrosive ground water. Protection against external corrosion is provided with cement mortar guiniting or hot applied coal-tar asphalt enamel reinforced with fiberglass fabric yarn.

It is necessary that a quantitative and qualitative assessment is to be made to arrive at the most economical and reliable pipe material.

5.9. Cast Iron Pipes

Most of the old Cast Iron pipes were cast vertically but this type has been largely superseded by centrifugally spun cast iron type manufactured up to a diameter of 1050mm (IS 1536-1989). Though the vertically cast iron pipe is heavy in weight, low in tensile strength, and liable to defects of inner surface, it is widely used because of its good lasting qualities.

Cast Iron pipes and fittings are being manufactured in this country for several years. Due to its strength and corrosion resistance, it is preferable to have coating inside and outside of the pipe.

Centrifugally cast iron pipes are available in diameters from 80mm to 1050mm and are covered with protective coatings. Pipes are supplied in 3.66m and 5.5m lengths and a variety of joints are available including socket and spigot and flanged joints.

The pipes have been classified as LA, A and B according to their thicknesses. Class LA pipes have been taken as the basis for evolving the series of pipes. Class A allows a 10% increase in thickness over class LA. Class B allows a 20% increase in thickness over class LA. The test pressure and working pressure of different class of pipes are shown in table 5.4.

TABLE 5.4

S.No	Class of Pipes	Test Pressure (Kg/sq cm)	Working Pressure (Kg/sq cm)
1	Class LA	35	10
2	Class A	35	12.5
3	Class B	35	16

The pipes are spigot and socket type. When the pipes are to be used for conveying potable water, the inside coating shall not contain any constituent soluble in water or any ingredients which could impart any taste or odour whatsoever to the potable water, after sterilization and suitable washing of the main.

C.I. pipes can be used in corrosive soils and for waters of slightly aggressive character. They are well suited for pressure mains, Road crossings, Hilly areas, valleys, for OHSR Vertical connections and laterals.

5.9.1. Joints

Several types of joints such as rubber gasket joint known as Tyton joint, mechanical joint known as Screw Gland joint, and conventional joint known as Lead joint are used. Joints are classified into the following three categories depending upon their capacity for movement.

Rigid Joints

Rigid joints are those, which admit no movement at all and comprise of flanged, welded and turned and bored joints. Flanged joints require perfect alignment and close fittings are frequently used where a longitudinal thrust must be taken such as at the valves and meters. The gaskets used between flanges of pipes shall be of compressed fiberboard or natural or synthetic rubber. Welded joints produce a continuous line of pipes with the advantage that interior and exterior coatings can be made properly and are not subsequently disrupted by the movement of joints.

Semi Rigid Joints

A semi rigid joint is represented by the spigot and socket with caulked lead joint. A semi rigid joint allows partial movement due to vibration etc. The socket end of the pipe should be kept against the flow of water and the spigot end of the other pipe is inserted into this socket. A twisted spun yarn is filled into this gap and it is adjusted by the yarning tool and is then caulked well. A rope is then placed at the outer end of the socket and is made tight fit by applying wet clay, leaving two holes for the escape of the entrapped air inside. The rope is taken out and molten lead is poured into the annular space by means of a funnel. The clay is then removed and the lead is caulked with a caulking tool. Lead wool may be used in wet conditions. Lead covered yarn is of great use in repair work, since the leaded yarn caulked into place will keep back water under very low pressure while the joint is being made.

Flexible Joints

Flexible joints are used where rigidity is undesirable such as with filling of granular medium and when two sections cannot be welded. They comprise mainly mechanical and rubber ring joints or titan joints which permit some degree of deflection at each joint and are therefore able to stand vibration and movement. In rubber jointing special type of rubber gaskets are used to connect cast iron pipe, which are cast with a special type of spigot and socket in the groove, the spigot end being lubricated with grease and slipped into the socket by means of a jack used on the other end. The working conditions of absence of light presence of water and relatively cool uniform temperature are all conducive to the preservation of rubber and consequently this type of joint is expected to last as long as the pipes. Hence, rubber jointing is to be preferred to lead jointing.

5.9.2. Steel Pipes

Steel pipes of smaller diameter can be made from solid bar section by hot or cold drawing processes and these tubes are referred to as seamless. But the larger sizes are made by welding together the edges of suitably curved plates, the sockets being formed later in a press (IS:3589). The thickness of steel used is often controlled by the need to make the pipe stiff enough to keep its circular shape during storage, transportation and laying and also to prevent excessive deflection under the load of trench back filling. The thickness of a steel pipe is however always considerably less than the thickness of the corresponding vertically cast or spun iron pipe. Owing to the higher tensile strength of the steel, it is possible to make steel pipe of lower wall thickness and lower weight. Specials of all kinds can be fabricated without difficulty to suit the different site conditions. Due to their elasticity, steel pipes adopt themselves to changes in relative ground level without failure and hence are very suitable for laying in ground liable to subsidence. If the pipes are joined by a form of flexible joint, it provides an additional safeguard against failure. Steel pipes being flexible are best suited for high dynamic loading.

5.9.3. Ductile Iron Pipes

Ductile Iron is made by a metallurgical process that involves the addition of magnesium into molten iron of low sulfur content. The magnesium cause the graphite in the iron to precipitate in the form of microscopic (6.25 micron) spheres rather than the flakes found in ordinary cast iron. The spheroid graphite in iron improves the properties of ductile iron. It possesses properties of high mechanical strength, excellent impact resistance and good casting qualities of gray cast iron. Ductile iron pipes are normally prepared using the centrifugal cast process. The ductile iron pipes are usually provided with cement mortar lining at the factory by centrifugal process to ensure a uniform thickness throughout its length. Cement mortar lining is superior to bituminous lining as the former provides a smooth surface and prevents tuberculation by creating a high pH at the pipe wall and ultimately by providing a physical and chemical barrier to the water.

Ductile iron pipes have excellent properties of machinability, impact resistance, high wear and tear resistance, high tensile strength, and ductility and corrosion resistance. DI pipes having same composition of CI pipe, it will have same expected life as that of CI pipes. The ductile iron pipes are strong, both inner and outer surfaces are smooth, free from lumps, cracks blisters and scars. Ductile Iron pipes stand up to hydraulic pressure tests as required by service regulations. These pipes are approximately 30% lighter than conventional cast iron pipes.

Ductile iron pipes are lined with cement mortar in the factory by centrifugal process and unlined ductile iron pipes are also available. For more details reference may be made to IS 8329-1994 for Ductile Iron pipes.

Ductile Iron Fittings: The ductile iron fittings are manufactured conforming to IS 9523-1980.

Joints: The joints for ductile iron pipes are suitable for use of rubber-gaskets conforming to IS 5383.

5.9.4. Asbestos Cement Pipes

Asbestos cement pipes are made of mixture of asbestos paste and cement compressed by steel rollers to form a laminated material of great strength and density. Its carrying capacity remains substantially constant as when first laid, irrespective of the quality of water. It can be drilled and tapped for connecting but does not have the same strength or suitability for threading as iron and any leakage at the thread will become worse as time passes. However, this difficulty can be overcome by screwing the ferrules through malleable iron saddles fixed at the point of service connections, as is the general practice. These pipes are not suitable for use in sulphate soils. Due to expansion and contraction of black cotton soil, usage of these pipes may be avoided as far as possible in Black Cotton Soils, except where the depth of B.C. soil is clearly less than 0.9 meter below ground level.

The safety against bursting under pressure and against failure in longitudinal bending, though less than that for spun iron pipes, is nevertheless adequate and increases as the pipe ages. In most cases, good bedding of the pipes and the use of flexible joints are of greater importance in preventing failure by bending, than the strength of pipe itself. Flexible joints are used at regular intervals to provide for repairing of pipes, if necessary.

AC pipes are manufactured from class 5 to 25 and nominal diameters of 80mm to 600mm with the test pressure of 5 to 25 kg/cm².

AC pipe can meet the general requirements of water supply undertakings for rising main as well as distribution main. It is classified as class 5,10,15,20 and 25, which have test pressures 5,10,15,20, and

25 kg/cm² respectively. Working pressures shall not be greater than 50% of test pressure for pumping mains and 67% for gravity mains.

For further details, refer to IS 1592-1989.

Pipe Joints: There are two types of joints for AC pipes.

- Cast iron detachable joint, (CID) and
- AC coupling joint.

Cast Iron Detachable Joints

This consists of two cast iron flanges, a cast iron central collar and two rubber rings along with a set of nuts and bolts for the particular joint. For this joint, the AC pipes should have flush ends. For jointing a flange, a rubber ring and a collar are slipped on to the first pipe in that order; a flange and a rubber ring being introduced from the jointing of the next pipe. Both the pipes are now aligned and the collar centralized and the joints of the flanges tightened with nuts and bolts.

A.C. Coupling Joint

This consists of an A.C. coupling and three special rubber rings. The pipes for these joints have chamfered ends. These rubber rings are positioned in the grooves inside the coupling, then grease is applied on the chamfered end and the pipe and coupling is pushed with the help of a jack against the pipe. The mouth of the pipe is then placed in the mouth of the coupling end and then pushed so as to bring the two chamfered ends close to each other. Wherever necessary, change over from cast iron pipe to AC pipes or vice-versa should be done with the help of suitable adapters. I.S. 6530-1972 may be followed for laying A.C. pipes.

Advantages & Disadvantages

Some of the advantages of A.C pipes are non corrosiveness to most natural soil conditions, good flow characteristics, light weight, easy in cutting, drilling threading and fitting with G.I Specials, allowances for greater deflection upto about 20° with mechanical joints, ease of handling, tight joints and quick laying and back filling.

Asbestos cement pipe cannot stand high superimposed loads and may be broken easily, they are subjected to corrosion by acids, highly septic sewage. Approved bedding is necessary to reduce the possibility to flexure failure.

Generally AC pipes should not be used where (a) Strata of black cotton (expansive) soil, (b) Highly undulating regions and (c) Water logged areas are encountered. Being brittle, these are damaged by villagers by punching a hole in the pipeline

5.9.5. Concrete Pipes

Reinforced concrete pipes used in water supplies are classified as p1, p2 and p3 with test pressures of 2.0, 4.0, and 6.0 Kg/cm² respectively. For use as gravity mains, the working pressure should not exceed 2/3 of test pressure. For use as pumping mains, the working pressure should not exceed 1/2 of the test pressure.

Generally concrete pipes have corrosion resistant properties similar to those of prestressed concrete pipes although they have their own features, which significantly affect their performance. Centrifugal spinning of vibratory process makes concrete pipes. Centrifugally, spun pipes are subjected to high rotational forces during manufacture with improved corrosion resistance properties. The line of development most likely to bring concrete pressure pipes into more general acceptance is the use of P.S.C. pipes, which are widely used to replace reinforced concrete pipes.

Jointing of pipes

The methods of jointing employed for concrete pipes are bondage spigot and socket joint (Rigid and semi flexible). Collar Joint, and flush joint (internal or external) in accordance with IS – 783. Amendment – 1, 1991 provides that all non pressure pipes should have flexible rubber rings joints after 1995.

Collar Joints (Rigid)

The collars of concrete pipes are 15 to 20 cm wide. Caulking space varies from 13 mm to 20 mm according to the dia of the pipe. Caulking material is slightly dampened mix of cement and sand 1:1.5 just to form a clod when pressed in hand which is rammed with caulking iron. The caulking shall be firm enough so that to drive the point of a pen knife is difficult. The caulking should be done at both ends in a slope.

Every joint shall be kept wet for 10 days for curing. The section of the pipe line laid and jointed shall be covered with earth and sand immediately to protect from weather effects.

Spigot and Socket Joint (Rigid)

The spigot of each pipe is slipped home well into the socket of the pipe previously laid and adjusted in the correct position. The opening of the joint shall be filled with stiff mixture of cement mortar 1:2 which shall be rammed with caulking tool. After day's work any extraneous material shall be removed from the inside of the pipe and newly made joint shall be cured. The pipes are laid with sockets facing up the gradient.

Spigot and Socket Joint (Semi Flexible)

The joint consists of specially shaped spigot and socket ends on concrete pipes. A rubber ring is placed on the spigot which is forced into the socket of the pipe previously laid. This compresses the rubber ring as it rolls into the annular space between the two surfaces of spigot and socket. Stiff mixture of cement mortar 1:2 is then filled by ramming into annular space and rammed with a caulking tool.

5.9.6. Pre-stressed Concrete Pipes

While RCC pipes can cater to the needs where pressures are up to 6.0 kg/cm^2 and CI and steel pipes cater to the needs of higher pressures around 24 kg/cm^2 , the prestressed Concrete (PSC) pipes cater to intermediate pressure range, while RCC pipes would not be suitable.

The strength of a PSC pipe is achieved by helically binding high tensile steel wire under tension around a concrete core thereby putting the core into compression. When the pipe is pressurized the stresses induced relieve the compressive stress but they are not sufficient to subject the core to tensile stresses. The pre-stressing wire is protected against corrosion by a surround of cementations cover coat giving at least 25mm thick cover.

The PSC pipes are suited for water supply mains where pressures in the range of a 6 Kg/cm^2 to 20 Kg/cm^2 are encountered. The deflection in these pipes during laying is comparatively very small and these pipes cannot be cut to required size to make adjustments in gaps in pipe lines special closure units which consist of short double spigot pieces and a plain ended concrete lined steel tube with a follower ring assembled at each end are available for this purpose. The minimum length of closure piece available is 1.27 m. The exact length actually required at site has to be ordered to fill up the gap that can be known at site only when the gap is physically established. This all result in inordinate delay in completion of the work. In such cases concrete lined steel pipes, which can be cut to required sizes at site should be used to make necessary adjustment in length and to close the gaps at site.

Specials: The specials for these pipes such as bevel pipes, bends, flanged tees, tapers and adapters to flange the couplings are usually fabricated as mild steel fittings lined and coated with concrete.

In case of this type of pipe it is necessary to make adequate provision for as many number of branches as are required in future and to close these branches either by providing blank flanges or by installing sluice valves. Otherwise for making connection in already laid pipe, the section has to be emptied, breaking the portion of pipe and then employing a special closure unit which is not only costly but time consuming also. In this pipe tapping can be made under pressure but only a trained workman should do this.

It is worthwhile when designing the pipeline to make provision for as many branches as are likely to be required in the future and then to install sluice valves or blank flanges on these branches. It is possible to make connections to the installed pipeline by emptying breaking out and using a special closure unit but this is a costly item.

Joints: The standard joint consists of steel joint rings and a continuous solid rubber ring gasket. The field joint can be over lapping/sliding, butt-welded or with confined rubber ring as per the client's requirement. In the case of welded & rubber joint recess is normally grouted and the internal joint space may or may not be pointed with mortar. At present the pipes available in India use steel end rings welded at site.

The reinforced pre-stressed concrete pressure pipes have been in use since 1909 for water supply lines, water transmission lines.

Jointing: As per IS- 784, Pre-stressed Concrete pipes also apply for laying and jointing. These pipes have flexible joints to be performed by rubber gaskets. The pipes are provided with spigot and socket ends to receive rubber gaskets. The joint with rubber gasket remains water tight under normal service conditions. For rubber gasket IS – 5382 is available.

Physical behavior of P.S.C pipes under internal and external loads is superior to R.C.C pipes. This pipe is always in State of compression that is most favorable factor for impermeability. These pipes can resist high external pressure. The protective cover of cement sand mortar which covers tensioned wire wrapping by its ability to create and maintain alkaline environment around the steel inhibits corrosion.

It can therefore be said that P.S.C pipes are unavoidable due to inherent economic advantage but cannot be considered preferable in all cases due critical precautions needed in laying and jointing

5.9.7. Plastic Pipes

Plastic pipes are produced by extrusion process followed by calibration to ensure maintenance of accurate internal diameter with smooth internal bores. These pipes generally come in lengths of 6 meters. A wide range of injection moulded fittings, including tees, elbows, reducers, caps, pipe saddles, inserts and threaded adapters for pipe sizes up to 200mm are available.

The role of plastic pipes and fittings for water supply and drainage is progressively increasing in India. The plastic pipes of the following standards are now manufactured and used for cold water supply; drainage and chemical pipe lines etc.

- (1) Indian Standard – 3076/1985 Low density polyethylene (LDPE) pipes for potable water supply
- (2) Indian Standard 4984/1987 High density polyethylene (HDPE) pipes for potable water supply Sewage and Industrial Effluents.

-
- (3) Indian Standard 4985, Unplasticised Polyvinyl chloride (PVC) pipes for potable water supply.

Properties of plastic pipes

TABLE: 5.5

Property & Unit	High density (HDPE) IS – 4984	Polyvinyl Chloride (PVC) IS – 4985
Softening point. °C	110-130	75-82
Ultimate tensile strength at 23°C, Kg/cm ²	265-280	445-600
Recommended temperature range for pressure pipe °C	-18 to +38	-1 to +60
flammability.		
Weathering characteristics effect of low temperature	Slow fair Same as for low density	self extinguish excellent tendency to become brittle at low temperature repeated freezing and thawing reduces working pressure
Chemical resistance	Good all round chemical resistance	Good chemical resistance
Safe working stresses at 20 °C Kg/cm ²	50	100
Pressure rating kg/cm ²	2.5,4,6 & 10 Fair	2.5.4.6.10 good relatively rigid only small
abrasion resistance	Same as for low density	bore pipe may be coiled.
flexibility		
Common jointing method	Heat welding and by compression fitting	Solvent welding and by rubber gaskets.
Available sizes in mm	50 to 400	20 to 315
Application	underground W.S. lines also for plumbing in buildings with special precautions.	substitutes for conventional pipes for plumbing of buildings except for hot water also substitute for conventional pipes in distribution systems.

PVC PIPES

The main advantages of PVC pipes are

- Resistance to corrosion
- Light weight
- Toughness
- Rigidity
- Economical in laying, jointing and maintenance
- Ease of fabrication

The PVC pipes are much lighter than conventional pipe materials. Because of their lightweight, PVC pipes are easy to handle, transport, and install. Solvent cementing technique for jointing PVC pipe lengths is cheaper, more efficient and far simpler. PVC pipes do not become pitted or tuberculated

and are unaffected by fungi and bacteria and are resistant to a wide range of chemicals. They are immune to galvanic and electrolytic attack, a problem frequently encountered in metal pipes, especially when buried in corrosive soils or near brackish waters. PVC pipes have elastic properties and their resistance to deformation resulting from earth movements is superior compared to conventional pipe materials specially AC. Thermal conductivity of PVC is very low compared to metals. Consequently water transported in these pipes remain at a more uniform temperature.

Rigid PVC pipes weigh only 1/5th of conventional steel pipes of comparable sizes. PVC pipes are available in sizes of outer dia, 20, 25, 32, 50, 63, 75, 90, 110, 140, 160, 250, 290, and 315mm at working pressures of 2,5,4,6, 10Kg/cm as per IS 4985-1988.

Since deterioration and decomposition of plastics are accelerated by ultraviolet light and frequent changes in temperature that is particularly severe in India, it is not advisable to use PVC pipes above ground. The deterioration starts with discoloration, surface cracking and ultimately ends with brittleness, and the life of the pipe may be reduced to 15-20 years.

Polyethylene Pipes

Rigid PVC and high-density polyethylene pipes have been used for water distribution systems mostly ranging from 15-150mm dia and occasionally up to 350mm.

Among the recent development is the use of High-Density Polyethylene pipes. These pipes are not brittle and as such a hard fall at the time of loading and unloading etc. may not do any harm to it. HDPE pipes as per IS 4984 -1987 can be joined with detachable joints and can be detached at the time of shifting the pipeline from one place to another. Though for all practical purposes HDPE pipes are rigid and tough, at the same time they are resilient and conform to the topography of land when laid over ground or in trenches. They are coil able, easily be bent in installation, eliminating the use of specials like bends, elbows etc., there by reducing fitting and installation costs. HDPE pipes are easy to carry and install. They are lighter in weight and can be carried to heights as on hills. They can withstand movement of heavy traffic. This would not cause damage to the pipes because of their flexural strength. HDPE has excellent free flowing properties. They have non-adherent surface, which reject (not attract) any foreign materials, which would impede the flow. HDPE pipes are anti-corrosive, have smooth inner surface so that there is less friction and pressure loss is comparatively less.

5.9.8. Glass Fiber Reinforced Plastic Pipes

Glass fiber Reinforced Plastic (GRP) pipes are now being manufactured in India conforming to IS 12709. The diameter range is from 350mm to 2400 mm. The pressure class is 3,6,9,12 & 15 kgs/sq.cm. The field test pressures are 4,5,9,13.5,18,22.5 kg/sq cm. The factory test pressures are 6,12,18,24 & 30 kgs/sq cm. Depending on the type of installation, overburden above the crown of the pipe and the soil conditions, four types of stiffness class pipes are available. Standard lengths are 6 & 12 meters, however custom made lengths can also be made. The specials are made out of the same pipe material i.e. Glass fiber Reinforced plastic (GRP).

The pipes are jointed as per the techniques; Double bell coupling (GRP) for GRP to GRP, Flange Joint (GRP) for GRP to valves, CI pipes or flanged pipes. Mechanical Coupling (steel) for GRP to GRP / steel pipe and Butt – strap joint (GRP) for GRP to GRP.

GRP pipes are corrosion resistant, have smooth surface and high strength to weight ratio. It is lighter in weight compared to metallic and concrete pipes. Longer lengths and hence minimum joints enable faster installation.

G.R.P. pipes are widely used in other countries where corrosion resistant pipes are required at reasonable costs. GRP can be used as a lining material for conventional pipes, which are subject to corrosion. These pipes can resist external and internal corrosion whether the corrosion mechanism is galvanic or chemical nature.

5.10. Strength of Pipes

Internal pressure, external loading, surge forces and change of temperature normally induce the stresses in a pipe, although torsion stresses can also arise. Internal pressure induces circumferential and longitudinal stresses, the latter developing where the line changes in size or direction, or has a closed end. A pipe is usually chosen so as to carry the circumferential stress without extra strengthening or support but if the joints cannot safely transmit the longitudinal stress, anchorages or some other means of taking the load must be provided. Longitudinal stress is absorbed by friction between the outside surface of the pipe and the material in which the line is buried.

A pipe must withstand the highest internal pressure it is likely to be subjected. External loads generally arise from the weight of the pipe and its contents and that of the trench filling from superimposed loads, including impact from traffic, from subsidence and from wind loads in the case of pipes laid above ground. If a pipe is laid on good and uniform continuous bed and the cover does not greatly exceed the normal, no special strengthening to resist external loading is generally necessary. Loading likely to arise from subsidence is best dealt with by the use of flexible joints and steel pipes. External loading becomes important usually when a line is laid on a foundation providing uneven support (e.g. across a sewer, trench or in rock under deep cover) or is subjected to heavy superimposed surface loads at less than normal cover. Careful bedding and trench filling to give additional support can often avoid the necessity of stronger pipes. The importance of good bedding under and around the pipe upto at least the horizontal diameter cannot be overemphasized and in some cases concreting may be required.

Excessive distortion of a steel pipe may cause failure of its protective coating but can be limited by the use of strengthening rings. This problem is only likely to arise in very large mains. Distortions at flexible joints can cause leakage. Valves require to be bridged by steel or reinforced concrete blocks so that the valve bodies are not stressed, as this could affect their water tightness.

In case of PVC pipelines, it should be noted that the coefficient of expansion of PVC, eight times greater than steel and considerable movement could take place in long lengths of rigidly jointed pipelines.

5.11. Structural Requirements

Structurally, closed conduits must resist a number of different forces singly or in combination.

- (a) Internal pressure equal to the full head of water to which the conduit can be subjected.
- (b) Unbalanced pressures at bends, contractions, and closures.
- (c) Water hammer or increased internal pressure caused by sudden reduction in the velocity of the water, by the rapid closing of a gate or shut down of a pump.
- (d) External loads in the form of backfill, traffic, and their own weight between external supports (piers or hangers). A reference may be made to the Manual Sewerage and Sewage Treatment.
- (e) Temperature induced expansion and contraction.

Internal pressure, including water hammer, creates transverse stress or hoop tension. Bends and closures at dead ends or gates produce unbalanced pressures and longitudinal stress. When conduits are not permitted to change length, variations in temperature likewise create longitudinal stress. External loads and foundation reactions (manner of support), including the weight of the full conduit, and atmospheric pressure (when the conduit is under vacuum) produce flexural stress.

5.12. Pipe Appurtenances

In order to isolate and drain the pipeline sections for tests, inspections, leaning and repairs, a number of appurtenances such as valves, manholes, insulation joints, expansion joints, anchorages etc are provided at various suitable places along the pipeline. Appurtenances are valves, which are installed in a pipeline to isolate and drain pipeline sections for test, inspection, cleaning and repairs, and for expulsion of air.

The appurtenances are classified to four types.

1. Controlling appurtenances such as Sluice valves, butterfly valves etc
2. Protective appurtenances such as air valves, non return valves/Reflex valves
3. Data collecting appurtenances such as pressure gauge and recorders, venturimeter, pizometer gauging points.
4. Miscellaneous appurtenances

Sluice valves

Sluice valves on main line are provided to stop and regulate the flow of water in the course of ordinary operations and in an emergency. The principle considerations in location of the valves are accessibility and proximity to special points such as branches, stream crossings, major summit points etc.

Sluice valves of the same size as per diameter of the main line pipe are normally used for isolating sections of pipe. Sluice valves are sometimes used for continuous throttling which may cause erosion of seats and lead to body cavitations. Wherever small flows are required, the bypass valve is more suitable for this purpose as compared to throttling the mainline valve. Fig. 5.6 presents the details of a sluice valve.

Scour Valve

Scour Valves are located in valley portions in the alignment of pipe lines, so as to facilitate emptying of the pipe line whenever required for maintenance of the pipeline. The outlet of the scour valve has to be connected to a natural drain. However, precautions must be taken to ensure that the wastewater from the drains does not enter the water supply pipelines. During installation of the valve, it should be ensured that it is always accessible for operation. A proper valve chamber with locking arrangement is required to protect the valve and prevent misuse. The size of scour valve shall normally be equal to half the diameter of the main line.

Air Valves

Air release valves are designed to expel air automatically from the pipelines, which tends to accumulate at the high points in the pipeline. Normally in gravity flow pipelines, when the pressure in the pipe falls below the atmospheric pressure, air has to be drawn in, to prevent collapsing of the pipes to prevent the pipe from such collapse (vacuum). Additionally Air valve have also to release any entrained air which might accumulate at high points in the pipe line during normal operations. For most cases in water works and pumping practice, two types of air valves are required. These are known as 1) large orifice air valve and 2) small orifice air valve.

Large Orifice Air Valve

The Purpose of this type of valve is to discharge air during filling or charging of mains and to admit air to mains while they are being emptied. They pass air at high rates of flow with small pressure difference either in to or out of the pipes on which the valve is fixed. The ball, which forms the valve element although buoyant, is rigid being covered with vulcanite. During normal service condition this ball is maintained in contact with its seating usually of leather backed rubber by the pressure in the main and cannot leave this seating except when the pressure falls practically to that of atmosphere. This occurs at various sections of a main when it is either being charged or emptied. When the pipes carrying a large orifice air valve, are empty, the valve is open and remains in that position until the ball is carried on to its seating by the arrival of water. Once on this seating and under pressure the valve cannot open and remains in that position even if the pipe is full of air until the pressure drops. It will be seen therefore that this valve will not release air accumulations under conditions of normal working pressure. When such a valve is discharging at a high rate, there is a risk that the ball although lying in a fully open position in the absence of water may nevertheless suddenly be caught in the escaping air stream and closed when it may refuse to open again until the pressure has been reduced. The ball of the valve in such a case would have to be held down during filling operation. This defect has been over come in a large orifice air valve of the advanced design known as kinetic air valve. In this air valve water or air enters from the bottom side of the ball and the air rushing around the ball exerts the pressure and loosens the contact with the top opening and allows the ball to drop down. When the solid water reaches the ball, however it is at once displaced and instantly closed.

Small Orifice Air Valve

The Purpose of this valve is to discharge air which may accumulate in sections of a main under working conditions, that is under the running pressure in the main. The orifice is relatively quite small and is sealed by a floating rubber covered ball at all pressures above atmospheric pressure except when air accumulates in this valve chamber. When air has accumulated to depress the water level sufficiently the ball falls away from out let orifice and the air escapes through this orifice until the water level rises again causing the ball to re seal the orifice. The diameter of the ball in a small orifice air valve is related to maximum working pressure and for a given size of orifice increase with this pressure. The orifice is not less than 2.5 mm in diameter.

Double Air Valves

In many instances both large and small orifice air valves are required at the same point on a main and it is usual in such cases to fit a combined air valve in a single fitting.

Air inlet valves are used at peaks. A manually operated sluice valve is introduced between the air valve and the main pipe to isolate the air valve for the repairs. Normally, air valves are used with size equal to $D/4$ where D is the diameter of the main pipe on which the air valve is placed.

Reflux valves

Reflux valves are also called check valves or non-return valves, which automatically prevent reversal of flow in a pipeline. They are useful in pumping mains when positioned near pumping stations to prevent back flow when the pump is shutdown. The reflux valve is normally provided on delivery side of each pump to prevent back flow into pump impeller and to avoid rotation of impeller in reverse back flow into pump impeller and to avoid rotation of impeller in reverse direction. The size of the valve is equal to the same size as the pipeline on which it is installed. Reflux valves shall have by pass valves, which can be used for priming or the suction line before starting of the pumps.

5.13. Anchor Blocks

Internal pressure including water hammer creates transverse stress or hoop tension. Bends and closures at dead ends or gates produce unbalanced pressure and longitudinal stress. When pipes are not permitted to change length, variations in temperature likewise create longitudinal stress. External loads and foundation reactions (manner of support) including the weight of the full conduit, and atmospheric pressure produce flexural stress.

Bends and closures at dead end reduce unbalanced pressure and longitudinal stress in the pipeline. Further when pipes are not permitted to change length due to variations in temperature, pipes also expand and create longitudinal stress. Anchorages are necessary to resist the tendency of the pipes to pull apart at bends and restrain or direct the expansion and contraction of rigidly joined pipes under the influence of temperature changes. A schematic representation of position of pipe in thrust block for different situations is shown in Fig.5.7

5.14. Pumping Station

Various pumping units required for pumping water are housed in a building known as Pumping Station or Pump House. Serious thought must be given to this aspect as a properly designed layout will not only give a neat and pleasant appearance but also results in ease of operation and maintenance. The material for the construction of pumping station should be fire proof. The building of the pump house should offer an attractive look which arouses public faith and confidence in the water supply scheme. Care should be taken to avoid dampness in case of construction of pump house below ground. Necessary provision for semi rotary pump for dewatering floor water should be made. The building should be very well tightened and ventilated. The height of roof should be sufficient to accommodate the functioning of over head crane. The door openings should be large enough so that the machinery can be taken in and out without any difficulty. In case of large station with a provision of ramp in front of door opening to enable the truck to load and unload crane. Door openings are generally located at one end of the building. The floor of the pump house should be properly sloped to carry off water when floors are washed or when there is water through a leaking joint inside the pump house. Care shall be taken to avoid water entering the electrical equipments.

See Annexure I for typical contents for preparation of detailed project reports.

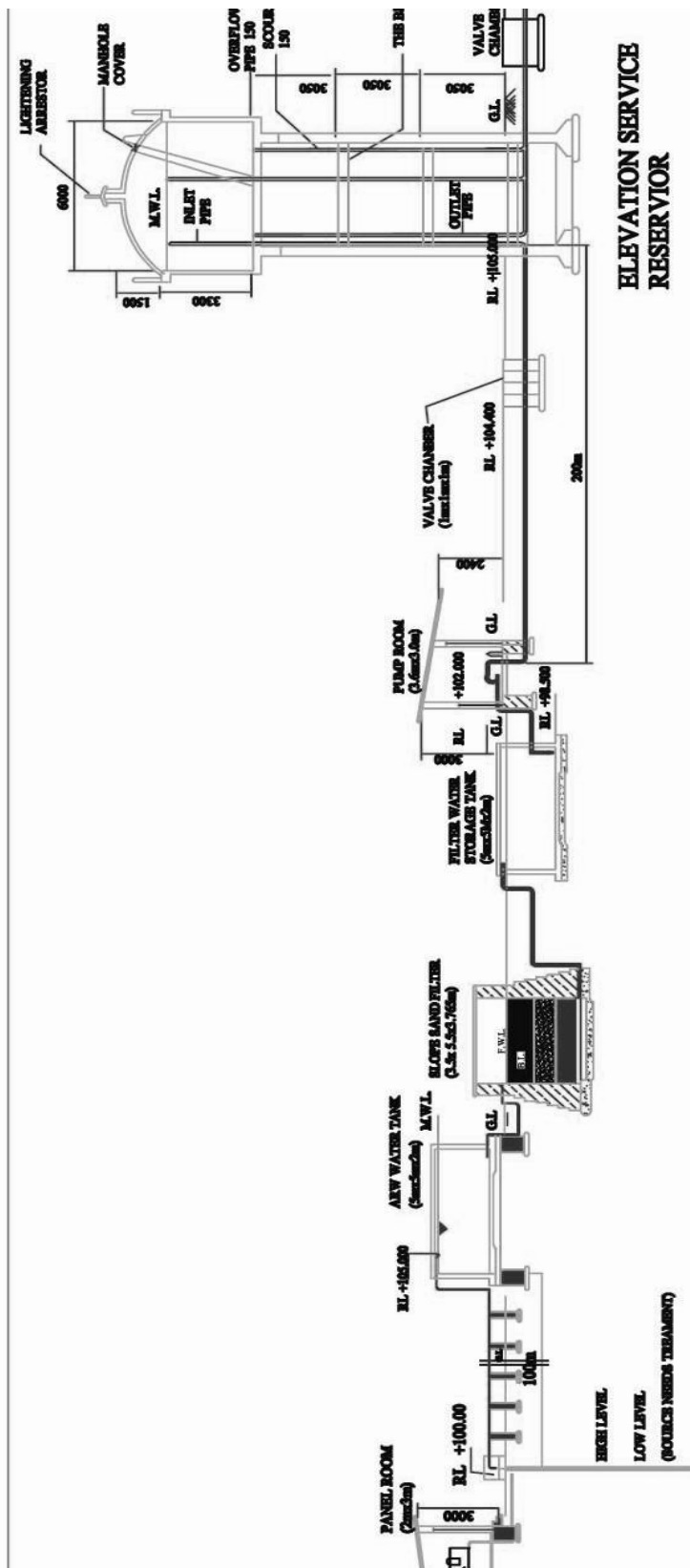
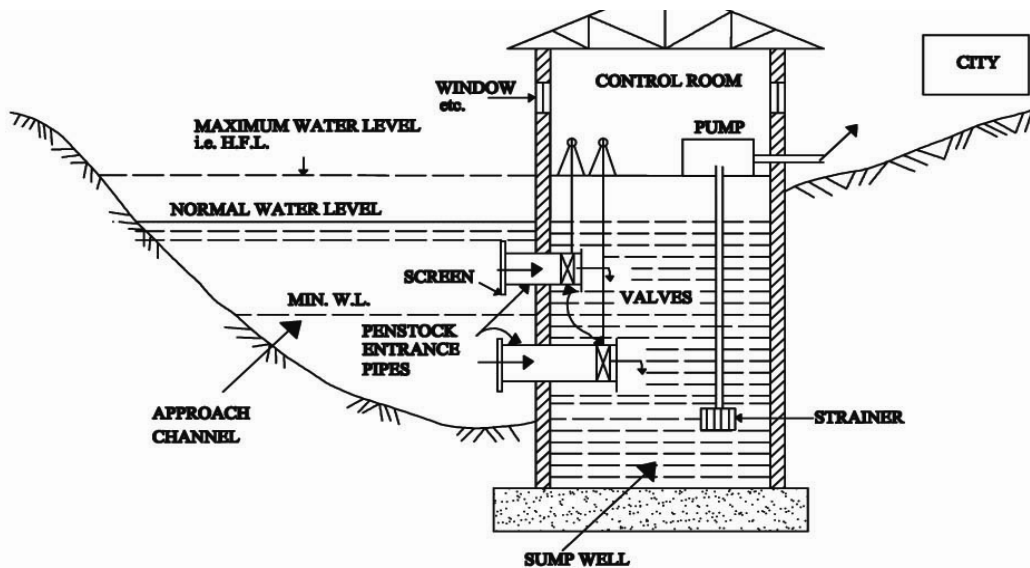


FIG:NO. 5.1 : SCHEMATIC DRAWING OF WATER SUPPLY SCHEME

ANDHRA PRADESH RURAL WATER SUPPLY & SANITATION PROJECT



**FIG NO. 5.2 : RIVER INTAKE ARRANGEMENT WHEN AN
APPROACH CANAL LEADS THE WATER TO SUMP**

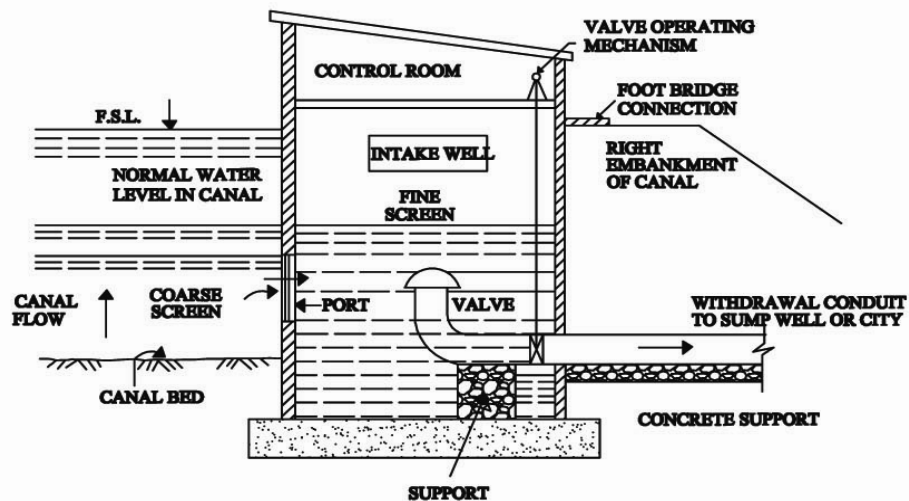


FIG NO. 5.3 : CANAL INTAKE WELL

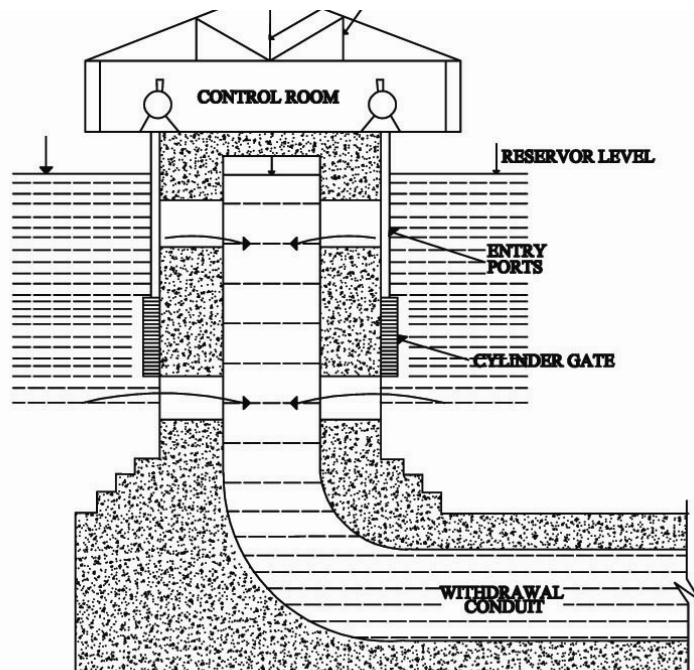


FIG NO. 5.4 : DRY INTAKE TOWER STANDING IN THE RIVER OR RESERVIOR

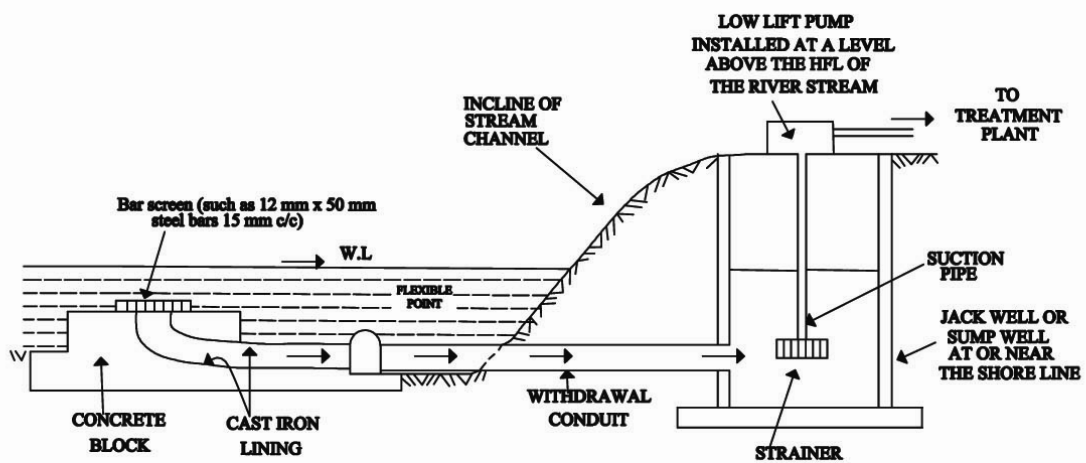


FIG NO.5.5 : SIMPLE CONCRETE BLOCK-SUBMERGED INTAKE

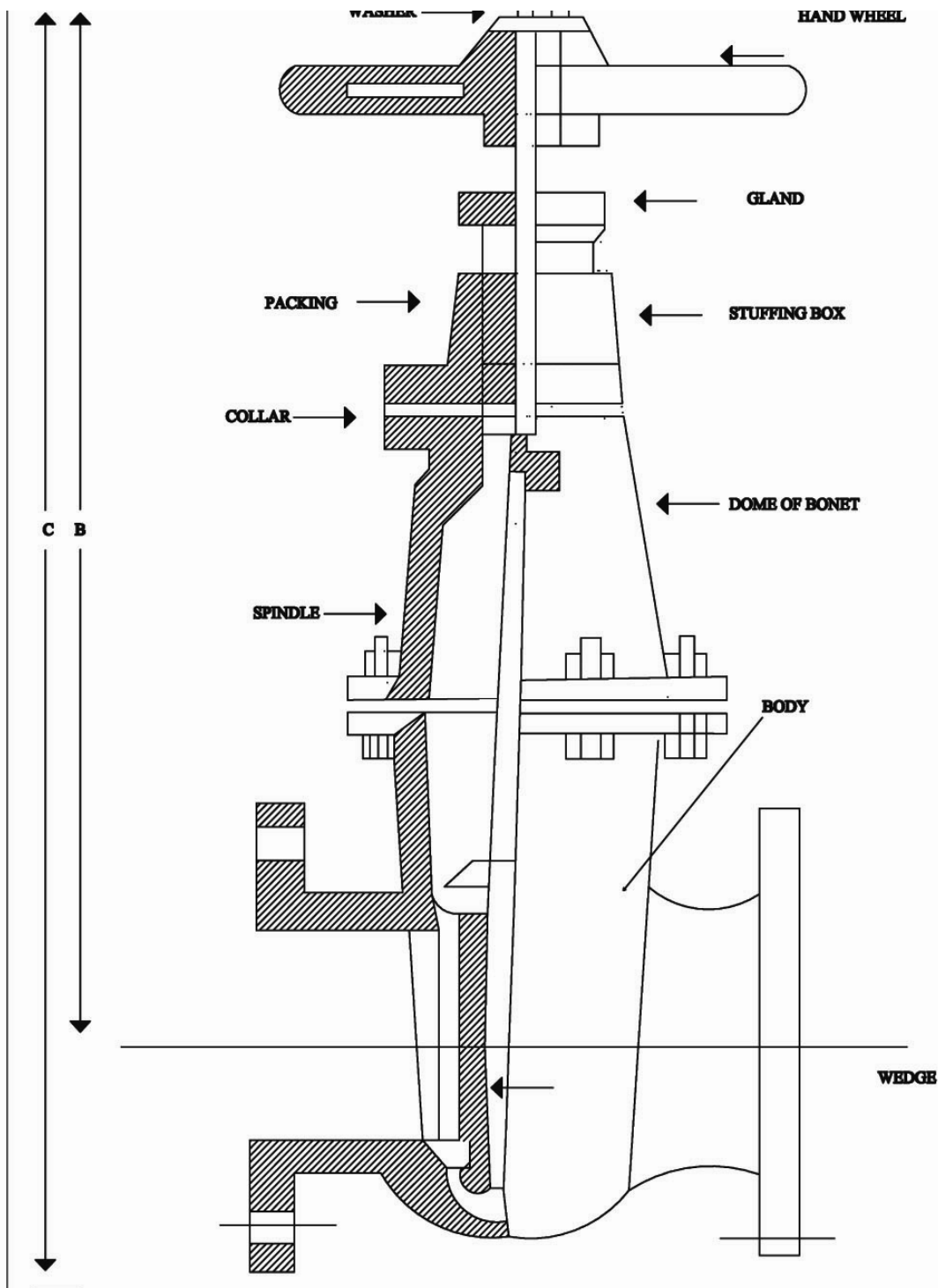


FIG NO. 5.6 :TYPICAL SKETCH OF SLUICE VALVE

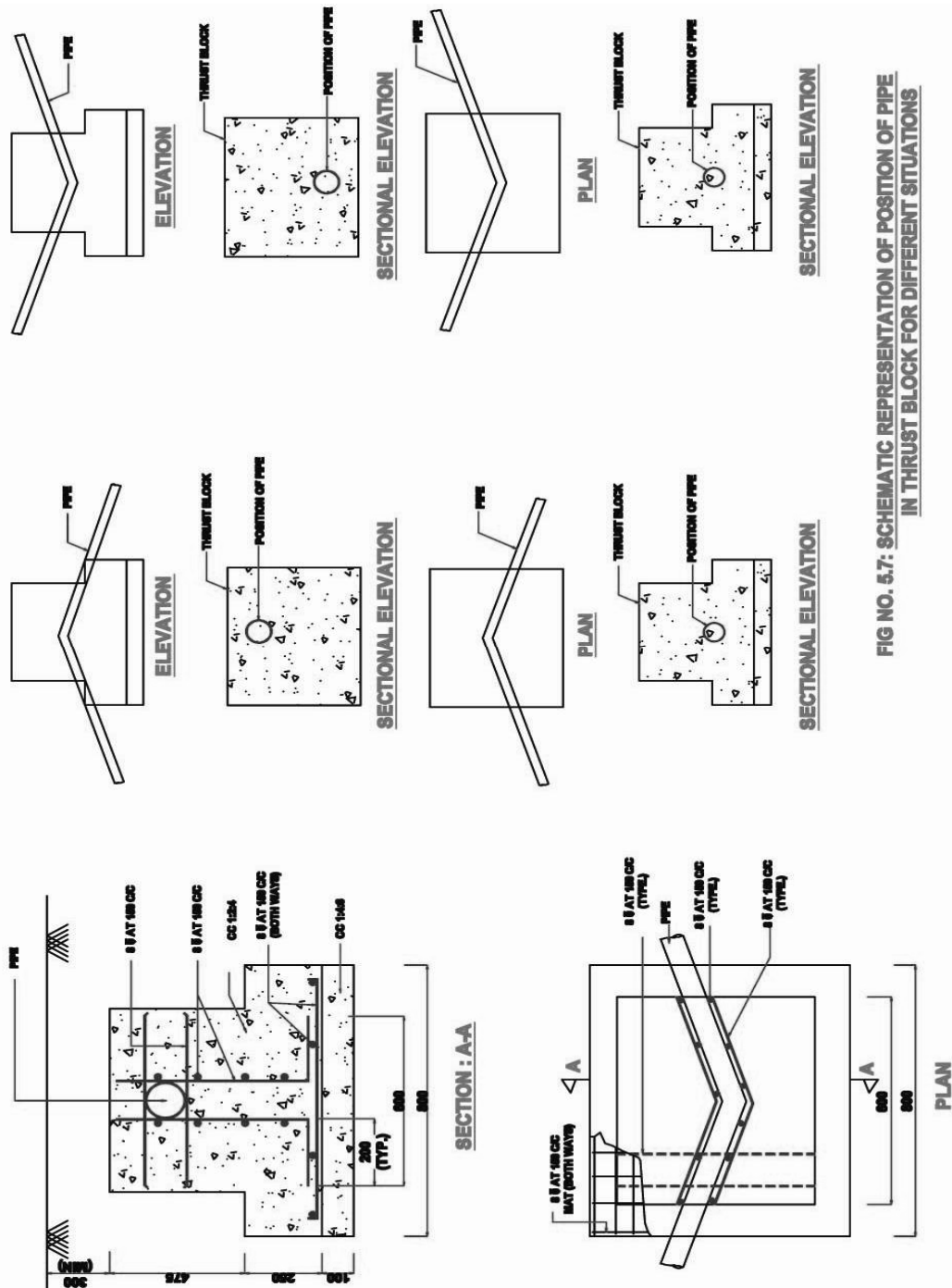


FIG NO. 5.7: SCHEMATIC REPRESENTATION OF POSITION OF PIPE
IN THRUST BLOCK FOR DIFFERENT SITUATIONS

CHAPTER – 6

6. PUMPING STATIONS, MACHINERY AND EQUIPMENT

Various pumping units required for pumping water are housed in a building known as Pumping Station or Pump House. Serious thought must be given to this aspect as properly designed layouts will not only give a neat and pleasant appearance but also result in ease of operation and maintenance. The building should be very well lighted and ventilated. The height of roof should be sufficient to accommodate the functioning of overhead crane.

6.1. General Requirements of Pumping Stations

The following points deserve careful thought while deciding the general overall requirements of a pumping system:

- Adjust the layout of pumping plant in such a way that there is no suction lift, if possible or there should be minimum suction lift. There should be least possible number of bends particularly on the suction side to keep the losses to minimum.
- Provide pumps of different capacities of maximum efficiency in case of variation in demand.
- Provide largest pumping unit in duplicate or make provision for two pumps in reserve.
- Make provision for over head traveling crane in case of large installations and each equipment installed in the pumping station should be accessible to be overhead crane without disturbing the other units. In case of vertical pumps with hollow shaft motors, the clearance should be adequate to lift motor clear off the face of the coupling and also carry the motor to service bay.
- Pumping station should be well lighted and well ventilated.
- Prefer location of the pumping station on the bank of the river to bed itself. Likelihood of floods, hill slides near the pumping station area should be critically examined.

6.1.1. Space Requirement and layout planning of Pumping System

The layout of various equipments requires skill and experience. Adequate space should be provided around each unit like pump, motor, valves, piping, control panels etc. Additional space should be provided for future expansion. Space requirement of equipment should be based on the catalogue of the equipment. It is necessary to have at least 1.5 m clearance between various equipments. Minimum 2 m wide unobstructed space should be available throughout the pump house building.

A clear space of not less than 0.914 m (3 ft) in width shall be provided in front of switch board. If there are any attachment or bare connections at the back of the switch board, the space (if any) behind the switch board shall be either less than 0.230 m (9") or more than 0.762 m (30") in width measured from the farthest out standing part of any attachment or conductor. If the space behind the switch board exceed 0.763 m in width, there shall be a passage way from either end of the switch board clear to the height of 1.830 m (6 ft).

Schematic diagrams of pumping stations lay out are shown in fig. 6.1, 6.2, 6.3

Schematic diagrams of RCC Pump house is shown in fig. 6.4

6.1.2. Foundation

The foundation of pump house building requires careful consideration. The function of the foundation is to transmit all dead load of the structure including weight transmitted by over head traveling crane and superimposed loads from a structure to the soil on which the structure rests. The width of the foundation is far more important than the depth.

6.1.3. Height of Pump House

For Vertical Turbine pumps

Height of Pump House in m. for Single floor pumps house for vertical turbine is shown in Table 6.1

TABLE:6.1

S.No.	HP of Pump	Pump floor to corbel top	Corbel top to roof slab bottom	Pump floor to bottom of roof top	Lifting equipment
1.	Upto 50 HP	--	--	5.5	Monorail
2.	51-150 HP	5.0	1.5	6.5	Hand operational crane
3.	151-300 HP	5.5	1.5	7.0	- do -
4.	301-500 HP	5.5	2.0	7.5	Electrically operated crane
5.	501 and above	5.5	2.5	8.0	- do -

For Centrifugal and Submersible pumps

Height of Pump for Centrifugal and Submersible Pumps in metres is shown in table 6.2

TABLE: 6.2

S.No.	HP of Pump	Pump floor to corbel top	Corbel top to roof slab bottom	Pump floor to bottom of roof total	Lifting equipment
1.	Upto 150 HP	--	--	4.0	Monorail
2.	151-300 HP	3.5	1.5	5.0	Hand operational crane
3.	301 and above	4.0	2.50	6.5	Electrically operated crane

Guide Lines

- Pump room should be constructed near to the source, to minimize the cable size and Length.
- Construction of a new pump room may be avoided, if the community prefers to use the existing Panchayat owned building, if situated nearby the source to minimize the estimate cost.
- Necessary lighting arrangements inside and outside the pump room should be provided for the convenience of the Pump Operator to operate the Pump set during night hours
- Proper earthing should be ensured as per IE rules,
- Pump room door should be fixed in such a way that it can be opened outwards only.
- The pump room shall be constructed for centrifugal/jet pump sets following the drawings and detailed estimates provided in the Manual on Rural Water Supply.

The details of bore well along with pump installation details as per site conditions are shown in schematic diagrams at Fig. 6.5 & 6.6

6.2. Panels

A panel is an essential component of the electrical machinery. Various functions which the panel board has to serve are

- To receive the power supply
- Distribution
- Controls
- Protection
- Under voltage relays
- Over current relay,

The components of panel board are:

- Starters
- Level controls
- Single phasing preventor
- 3 Phase indicators
- Dry run preventor
- Capacitors
- AVO meter

Starters

The principal methods of starting three phase squirrel cage motors are Direct Online (DOL), Star Delta and Auto-Transformer.

When using direct starting, the only control gear is a switch or circuit breaker which serves to isolate the motor from the supply. Some starters have two positions for the operating handle, Off and On (or Run). The Start position of the latter type cuts out the overload coils and this is the only difference between the two types of starters.

If the motor fails to start when the starter handle is moved to Start position, the handle should not be moved over to Run position but should be immediately returned to Off position otherwise both motor and starter will get damaged.

6.3. Transformers

Transformers are located out door which should be as near to the pump house as possible to keep the leads shortest.

The outdoor sub-station should have (1) lightning arrestors (2) Gang operated disconnections. In indoor sub-station circuit breakers are provided (3) Dropout fuses for small outdoor sub-stations (4) Overhead bus bar and insulators (5) Transformers (6) Current transformer and (7) Fencing and (8) Earthing-very comprehensive, covering every item in the sub-station in accordance with IS-3043.

6.4. Capacity of Motors

The power required to drive the centrifugal pump from shut off to maximum capacity varies. Power requirement is minimum at shut-off head and maximum at or near the maximum capacity. Operations of pumps at heads below the normal increases the load of the drive and sometimes causes overload.

Therefore in order to avoid continuous overloading of the electric motor, the rated KW of the motor should exceed the KW calculated by the following percentages:

-
-
- For a pump requiring up to 1.5 KW, add about 50%
 - For a pump requiring from 1.5 to 3.7 KW, add about 40%
 - For a pump requiring from 3.7 to 7.5 KW, add about 30%
 - For a pump requiring up to 7.5 to 15 KW, add about 20%
 - For a pump requiring up to 15 to 75 KW, add about 15%
 - Above 75 KW about 10%.

Electric motors below 1/3 hp are not used for driving pumps. For 50 c/s frequency, the speed of an induction type motor may be about 1450 to 2900 rpm. Indian Standard 6295 specifies an allowance for the falloff over all efficiency up to 2% for electric motors for every 300 m altitude above mean sea level. Care should be taken in selecting the motors. It should be large enough to avoid overload and not too large that power is wasted.

Performance of Motors

Motors are designed to produce their rated horsepower, torque and speed at specific line voltage, line frequency and ambient temperature. The motor will work at a specific efficiency and power factor when all these conditions are met.

The normal operating conditions of a motor are indicated on its name plate with values of horse power, speed, ambient temperature and frequency. Any change in conditions from the motor name plate will change the performance of the motor.

Voltage

Motor is designed to operate satisfactorily at the name plate rating with $\pm 10\%$ variation from name plate voltage. Within $\pm 10\%$ voltage, a motor is expected to operate pump safely and continuously. A motor should never be expected to operate continuously beyond $\pm 10\%$ voltage. If the motor voltage never increases beyond 70%, the centrifugal pump would not reach normal operating speed.

Different motor voltage from name plate rated voltage will affect the motor speed, power factor and efficiency established for rated voltage and load. An induction motor will run at several rpm faster than name plate speed at 10% over voltage and several rpm below name plate speed at 10% under voltage.

Single Phasing on Three Phase Motor

Occurrence of single phasing on three phase motor will cause overheating and possible burnout. Theoretically a three phase machine will not start on single phase but in the running position if one line is broken motor will continue to run but with unbalanced current loading as described below.

In case of both star delta connecting motors, a break in one phase of the supply means that the output taken from the machine must be reduced to less than half of the normal output. To minimize the risk of such a break in one phase of the supply, check the distribution fuses. They should have the capacity of at least three times the full load current rating of the motor.

Earthing

Various types of earth electrodes in use are Rod and Pipe electrodes, Strip electrodes and Plate electrodes. Round and flat sections of copper and GI wire are used for earthing purpose. No earth wire shall have cross sectional area less than 3 mm^2 , if copper wire is used and 6 mm^2 if GI wire is used.

6.5. Pumps

A pump is a machine which when driven by power from external source, raises water or any other fluid from lower level to higher level or increases the pressure i.e., it receives mechanical energy and

raises the potential energy of fluid. Hence, the pump is just the inversion of hydraulic prime mover. Mainly there are two types of pumps, rotodynamic or dynamic pressure pumps and reciprocating or positive displacement type. The behaviour of positive displacement pumps is much different from that of the dynamic pressure pumps.

The classification of pumps from point of view of direction of flow, depending upon the type of impeller, is made as under:

- a) **Radial Flow Pumps:** Ordinarily all centrifugal pumps are manufactured with radial flow impellers.
- b) **Mixed Flow Pumps:** This is modification of radial flow type with which a pump discharges large quantity of water. Flow is the combination of radial and axial through the impellers. These pumps are used mostly where large quantity of water is required to be lifted.
- c) **Axial Flow Pumps:** It is actually a roto dynamic pump because it does not generate centrifugal force for building up pressure. Pressure is generated by flow of liquids over the blades of aerofoil section just like the lifting action of the wings of an aero plane. Axial flow pumps are manufactured for very large quantity of flow at comparatively lower heads.

6.5.1. Hand Pump

This is a vertical piston pump in which water is moved by the direct push of plunger, piston or bucket which moves in a closed vertical cylinder. In operation, during the upstroke, atmospheric pressure forces water into the cylinder, during the down-stroke, this water is transferred from the lower to the upper side the piston.

The pressure of air at sea level, under ideal conditions, is enough to raise a column of water to 10 m in a vertical pipe in which perfect vacuum has been created. Conditions in the field are generally far from ideal because of air leaks, imperfections, presence of air in water etc., In practice suction lift or the distance from the cylinder to the lowest water level should never be more than 5m to 6m.

The UNICEF designed Hand Pumps which are popularly known as listed below and are covered by various Indian Standards.

- a) Shallow Well Hand Pumps - IS-14106/1996
- b) Deep Well Hand Pumps
 - i) India Mark II - IS-9301/1990
 - ii) India Mark III - IS-13056/1991
 - iii) Extra Deep Well - IS-13287/1992

General features of India Mark III (VLOM) Deep. Hand Pump

These pumps are called as “village level operation and maintenance pumps” (VLOM) hand pumps (IS-13056/1991). India Mark III hand pump is identical in design to India mark II and has following lead features.

Pump Head:

- Pump head is provided with a centre hole of 75mm dia on the bottom flange.
- The handle assembly has 70mm dia bearing housing
- An additional 6mm plate welded with guide bush is provided separately.
- Stroke length of 125mm is provided

Water Tank:

- Water tank assembly is fitted with 65mm n.b. coupling to suit 65 n.b. GI riser pipe Water tank height has been increased by 25 mm to offer more storage and to prevent over flow due to increased stroke.
- Pedestal height has been reduced by 25mm which offers more convenient pump height to the user.

Cylinders:

- 65mm i/d C.I. open top cylinder with brass liner is fitted with a bottom and cap to suit check valve and top end cap to facilitate extraction of plunger and check valve assemblies for repairs without lifting the riser main.
- Nitro rubber washer is provided in place of leather in the piston assembly.
- The cylinder assembly will have top cylinder cap to suit 65 mm n.b. medium class riser pipe and the bottom cylinder cap will have conical housing to receive pick up check valve. The top end cap is threaded to suit 65 mm dia n.b. threads while the lower cap has 50mm n.b. threads.
- The cylinder height will be 355mm as against 304 mm for India Mark II.
- Upper valve guide and check valve will be two piece valve.
- Special design for conical housing and pick up check valve.
- Modified spacer with collar to centralize nitride bucket washer.

Common and non-Common Features of Mark II, Mark III and Extra Deep Well Hand Pumps are shown in table 6.3

TABLE:6.3

Feature	Common	Non-Common
Head Assembly	Mark II and Mark III	(a) Extra Deepwell
Handle Assembly	Mark II and Mark III	(a) Extra Deepwell
Third plate	Mark II, Mark III and Extra Deepwell	--
Water Tank	Mark II and Extra Deepwell	c) Mark III
Stand Assembly	Mark II and Mark III	d) Extra Deepwell
Connecting Rod	Mark II, Mark III and Extra Deepwell	
Cylinder Assembly	--	e) Mark II, Mark III and extra deepwell

6.5.2. Dynamic Pressure Pumps**Deep well or Vertical Turbine pump**

For obtaining ground water, bores are drilled even upto 150 m depth. The pump used under this situation is a multistage pump with vertical spindle . The pump is kept well under water. All the impellers and atleast 3 m of suction pipe, with a strainer at the end, are placed below the water level. The motor or the engine is fixed on the ground level. The vertical shaft is co-axial with the rising main or delivery pipe and it is supported by several bearings which are water lubricated. This pump has an overall efficiency of about 70% to 80%. Such pumps are capable of discharging 300 to 52000 litres/minute. These pumps are used for lifting water from deep tube-wells.

In turbine pumps water flows in general direction of the axis of the pump through number of stages depending upon the head required. This pump is very compact. A powerful pump can be built in

small dia bores holes when larger flows are required. This pump works at much higher speed, which makes the system compact and lighter but it renders it more liable to break down and more difficult to repair. In case of rural electric supplies where voltage is not adequate or with engines not properly maintained, this pump works at reduced efficiency because of the reduced rate of rotation than the designed one

When pump is driven by an engine, a belt drive is employed for small and medium type pumps and toothed gearing for large sizes. The advantage of directly coupled pumping set is that it requires about 25% less power. It is necessary to have impellers and guide vanes made of corrosion resistant metals. The deep well turbine pump installation practically seals tube well from the exterior, thus protecting water from contamination.

Criteria for selection of Turbine Pumps:

- Dia of open well or bore well
- If bore well, dia and length of tube along with total depth
- If bore well, whether it has been tested for vertically and if tested, results of vertically test.
- Depth of water level from the ground level in the driest season.
- Expected depression in water level at the specified discharge.
- Quantity of water required in lpm.
- Vertical static height from the ground level to the delivery outlet point.
- Running length and size of delivery pipe
- Number and sizes of fittings to be used on the delivery side.
- Type of driver, electric motor or engine
- In case of electric motor, volts, cycle etc.
- In case of oil engine drive, full particulars of engine, engine pulley dia and direction of rotation of engine.

6.5.3. Submersible pumps

The submersible pumping set should conform to I.S 8034-1989 with latest amendment. The pump should be fitted dynamically balance enclosed type impeller. Each impeller shall be balanced dynamically to grade of G 6.3 (6.3mm/s). The pump shaft shall be guided by bearing provided in each stage bowl & in the suction and discharge casing. The surface finish of shaft or of the protecting sleeves should be 0.75 micron Ra Max. The inlet passage of the suction casing shall be stream lined to avoid eddies. The suction case shall be fitted with a strainer of corrosion resistant material. Suitable sand guard shall be provided just above the suction case bearing to prevent the entry of foreign material into suction case. The pump should be provided with the non return valve above the pump discharge case with standard flanged connection. The individual casting part or pump as a whole in assembled condition should be able to withstand a hydrostatic pressure of 1.5 times maximum discharge pressure. The gaskets & seals used shall conform to I.S 5120-1968 or latest. The cable clamp of adequate size be supplied for fixing submersible cables to the rising main pipes.

The pump shall be directly coupled to a submersible motor. The submersible motor shall be squirrel cage induction motor conforming to I.S 9283-1979 or latest capable of operating on 415+ 6% volts, 3 phase 50 cycles. A.C. supply both pump and motor shall run at 2900 R.P.M. The water lubricated thrust bearing should be of adequate size to withstand the weight of all rotating parts as well as the

imposed hydraulic thrust. The motor shall be protected by means of cable glands, rubber seals etc from ingress of bore well water, sand and other foreign material. The motor shall be provided with breathing attachment like bellows, diaphragm etc. to compensate the volumetric variation due to change in the temperature. The motor shall be made of corrosion resisting material or suitable materials to resist corrosion under normal conditions. The rotor shall be provided with shaft protecting sleeves having a surface finish of 0.75 micron. The starter shall be star delta. The submersible cable of finolex make for submersible motor shall conform to IS 694 (Part-III)-1964 or latest. The flanged column pipe shall conform table 2 I.S 1239 (Part-1) 1979 or latest (Medium Class) Table – 2.

Normally they are installed at 1.5-2.0 m below the lowest safe yield level during summer under continuous operation. Hence it is necessary to install electronic water level indicators to read the water level in the bore well ensuring the required minimum submergence (1.5m) also to avoid drawing of the silt/sand from the bottom. It is preferable that the lowest part of the pump is 3m above bottom of the well. The casing pipe is taken to a height of about 45cm above the ground level and is covered with a bore cap. The H.P of motor shall be 15% in the excess of maximum H.P required under all heads of working. Performance guarantees shall be based on laboratory tests corrected for field performance.

Submersible pumps are often a 'tight' fit in tube well as their outside dia is usually only 1-2 cm less than the internal hole of the well casing. Consequently great care is needed during installation and removal of these pumps. A water proof electric cable connects the motor.

6.5.4. Jet Pump:

In this type of pump the kinetic energy of high velocity jet of water is converted into water pressure in the portion of suction pipe immediately following a restricted opening or throat similar to discharge of ventury meter. These pumps are also called sometimes Ejector Pumps. These pumps are less efficient than any other type of pump discussed so far but these have certain advantages which make these pumps suitable for very small supplies where conditions favour their installation. Jet pump is essentially a small centrifugal pump which forces water down a well at high pressure. This high pressure water, issuing from a jet into the throat of a venture tube, causes a larger volume of water at lower pressure to be delivered from the rising main. In this type of pump priming is necessary. Unless the whole system is filled with water, the operation will not start.

The jet pump should not be installed where the suction lift is less than 6 m because a more efficient centrifugal pump can work under this situation in a better manner. Jet pumps work normally with a lift ranging from 6 m-55 m below ground and discharges range 570 lph to 22500 lph against a delivery head of about 15m. At all times jet must be covered by at least 1.5m of water so that well is not emptied completely.

Horizontal Centrifugal Pump

The specification covers the design, performance, manufacturing, shop testing, and erection, testing and commissioning at site of the horizontal centrifugal pumps.

The design, manufacture and performance of the horizontal centrifugal pumps shall confirm to the latest revisions of the following codes and Indian Standards, in addition to other stipulations and standards mentioned elsewhere in the specification.

IS: 1520	Horizontal centrifugal pumps for clear cold fresh water
IS: 5120	Technical requirement rotodynamic special purposes pumps
IS: 5639	Pumps handling chemicals and corrosive liquids
IS: 5659	Pumps for process water

Vertical Centrifugal Pump

The specification covers the design, performance, manufacturing, shop testing, erection, testing and commissioning at site of the vertical centrifugal pumps.

The design, manufacturer and performance of the vertical centrifugal pumps shall conform to the latest revisions of the following codes and Indian Standard in addition to other stipulations and standards mentioned elsewhere in the specification.

IS: 1710 Vertical Turbine Pumps for clear, cold, fresh, water.

IS: 5120 Technical requirements for roto dynamic, special purpose pumps.

The material of construction for the various components of the pumps shall conform to the applicable standards like 'American Society of Testing & Material (ASTM)' and Indian Standards.

6.6. The Basic Concepts of Pump Engineering

Water when raised from lower level to higher level gains potential energy and an important aspect of the duty of the pump is such increase in the energy of the water what is termed as Head of the pump

When a tank is to be filled in a definite time period, the quantity of water in a definite time period is the rate of Discharge.

To raise the head of water and to deliver it at a certain rate, power is required to drive the pump. This may be manual, mechanical or electrical. The pump takes power from the 'Drive' and delivers it to water. In this it consumes some of the power for itself. Hence the ratio of the power delivered to the water to the power taken from the drive expresses the Efficiency of the pump.

Head considerations

The pump sucks water and discharges it at a specified point. So the total head of the pump consists of two parts: (1) the suction side and (2) the delivery side.

Suction Side: On suction side, the pump draws water either (a) From the suction sump wherein water is below the center line of the eye of the pump, or (b) from a suction well where in level of water is above the center line of the eye of the pump.

When the suction level is below the center line of the pump, the pump (1) lifts water through the distance between the center line of the pump and the suction water level when the pump is working. This is called static suction lift (h_{ss}). (2) The pump also overcomes the frictional losses in the suction pipe line and pipe fittings.

Suction Lift (h_s): This is the total of static suction lift (h_{ss}), the frictional losses in suction piping and the entrance losses at the beginning of the suction piping (h_{fs}) and the pressure reduction due to velocity in suction pipe (numerically equal to the velocity head; $(v_s^2/2g)$)

$$\text{Therefore } h_s = h_{ss} + h_{fs} + v_s^2/2g$$

Suction lift as measured on the test bed is the reading indicated by vacuum gauge or water or mercury manometer at the suction side of the pump plus or minus the vertical distance between the point of the gauge or manometer and the center line of the pump, according to the point of attachment of gauge above or below the center line of the pump.

Total Head (H): The total head of the pump comprises of (1) the suction head and (2) delivery head. It may be noted that the total head would be either the addition of suction lift head and delivery head

the difference between the delivery head and suction head as the case may be. The technical terminology for Head measurements in pumps is shown in Fig. No. 6.7.

The total head is called the Pump Head, Pump Total Head or Total Dynamic Head. The total head H developed by the pump is customarily meters of water column in metric measure. Head in meters can be converted into pressure in kg/cm^2 by dividing the head in meters by 10 ($1\text{kg/cm}^2 = 10\text{ m head of water}$), Average fluid velocity V , is in meters/second (m/sec) where $V = Q/A$, Q is discharge in m^3/sec and A is cross sectional area of flow passage in square meter (m^2). Acceleration due to gravity g , in meters/sec is assumed to be $9.81\text{ m}^2/\text{sec}$. Technical terminology for head measurement is illustrated in diagram 6.1.

Friction Losses or Friction Head in Piping System

This is the equivalent head required to overcome the resistance of pipe, valves (foot valve, gate valve, non return valve etc) and fittings (couplings, elbows, bends, tapers, tees, reducers etc.) Friction head exists both on suction and delivery sides of the pump and varies with the flow rate, size of piping, interior condition of pipe and type of pipe.

Various types of losses in pipes under different conditions such as sudden enlargement, sudden contraction and from pipe to open container etc. have been discussed. The losses are more suitably expressed in metres of water column and are to be determined as accurately as possible with the help of tables as Stated above. The total frictional head loss thus computed is to be multiplied by 1.1 for safety reasons.

Determination of loss of head in pipe line and pipe fittings:

Such losses are classified as follow:

- a) Loss of head in pipes
- b) Loss of head due to enlargement of cross section of pipes
- c) Loss of head due to contraction of cross section of pipes
- d) Loss of head due to bends in pipes
- e) Loss of heads due to pipe fittings such as tees, valves, expansion joints and strainers with foot valves etc

6.7. Pump Characteristics

Net positive suction head (NPSH)

Net positive suction head is total energy (head) at the inlet flange of the pump (in relation to zero absolute pressure head of liquid, corresponding to vapour pressure of liquid). Two types of NPSHs are to be considered:

- a) The Available NPSH (NPSHA): This is the function of the system its static head or lift, friction head, and the vapour pressure of the liquid being handled. It is the available energy (head) in metres at the inlet of pump. It is possible to control one phase of available NPSH by altering the physical arrangement of an installation, if change can be made in piping, by lowering the pump or by raising water level in source for satisfactory operation.
- b) Required NPSH (NPSHR): This is the function of the pump design and varies with the make and model of the pump and also with capacity and speed of any given pump. It is the energy head required, usually Stated in metres of water, to overcome pump's internal head losses, for instance turbulence, losses created in suction passage of the pump and loss incurred by the

liquid passing the inlet edge of the impeller vanes. The required NPSH for a particular pump must be obtained from the manufacturer. Pumps of high specific speed have high NPSHR.

Each pump has certain requirement of NPSH which is indicated by the pump manufacturers generally in the performance curve. While designing the level of the pump centre line with respect to the lowest level form where water is to be picked up, NPSH required by the pump must be taken into account and it must be ensured the NPSH available is higher altitudes, the lower atmospheric pressure will reduce the NPSH available. This should also be considered while fixing the centre line of the pump.

The available NPSH should always be more than the required NPSH for satisfactory pump performance. Failure to meet NPSH requirements of the pump selected will result in cavitations of the pump impeller and very low pumping efficiency.

6.8. Pump Priming

When the pump is at rest for sometime, water leaks from the casing of the pump and suction pipe and to suction sump. The casing and the suction pipe thus remain filled with air. If pump is started under this condition, it will produce only negligible pressure difference across the impeller which is inadequate for the creation of proper vacuum to enable water to rise along the suction pipe to reach the impeller. It becomes, therefore, necessary to first fill up suction pipe and casing of the pump with water. This filling up operation is termed as 'Priming'.

There are several priming methods which may be used for many types of pumps:

1. With a flooded suction
2. A bypass around the discharge check valve
3. The separate air drawing pump from the casing at the main pump to give priming action
4. An ejector for priming
5. A priming tank holding the supply of water
6. Vacuum pumps manually and automatically controlled to prime the main pump.

In case of small pumps, priming is accomplished by pouring water directly in the casing through a funnel. The air vent cocks provided over the casing are kept open for expulsion of air during priming process. When the air has completely been displaced from the pump casing and suction pipe and the piping system on suction side is throughout filled with water, the air cocks are closed and the pump started.

Foot Valve

This is a sort of check valve which is fitted at the bottom or foot of the suction line. The foot valve remains open while the pump is running. When the pump is stopped, the foot valve closes and it prevents water in the suction line to drain back to suction sump as long as the seat of the foot valve closes tightly.

At several occasions the foot valve fails to seat tightly and suction piping gets emptied. In most of the cases the rate of leakage is small and it is usually possible to start the pumping after doing required priming of the pump. In case, water being pumped contains small particles of foreign matter, the trouble is further increased. Another big disadvantage in the application of foot valve is that it has high frictional loss.

The foot valve should be of hinged flap type with a clear passage for water of at least the same area as that of the suction pipe. The foot valve should be provided with an efficient strainer to prevent foreign matter from being drawn into the pump. The clear area of the openings of the strainer should be at

least 3 times the area of suction pipe for clear water. Much more area is required for water containing foreign matter.

Suction Sump and Suction Piping

For best results, the sump or sump bays are located parallel to the direction of flow. In case the flow approaches from an angle it creates high local velocities and dead spaces which result in non-uniform velocity and increase in entrance losses. The pipes should be arranged in such a manner that the flow to any pump should not be required to pass another pump before reaching it. The inflow in the suction sump should be at the farthest end from the suction pipe avoid effect of turbulence.

Delivery Pipes and Fittings

The general requirements of delivery pipe and fittings as indicated in 'layout plan of pumping station' as shown in Fig.No.6.7. A check valve (non-return or reflux valve) and a gate (sluice) valve is installed on the delivery line. The check valve is fixed between the pump and the sluice valve to protect the pump from abnormal pressure and to avoid water getting back through the pump upon shut down or power failure. The sluice valve is used for priming operation and starting. The sluice valve is closed before stopping the pump. When a reducer is required in between pump delivery end and delivery line because of the change in diameters of the two, the reducer is fixed between the reflux valve and the pump. Pressure relief valves, air valves, reflux valves and scour valves are also provided on the delivery line.

Manifolding the discharge header is a usual practice in the design because with this parallel operation can be achieved readily. Interconnecting of discharge headers affords additional system flexibility and added protection in the event of pipe failure.

Devices for reducing water hammer effect will provide a fairly good idea of the requirement of fittings required for a particular system. The design of discharge and suction line required to be connected with reciprocating type pump is done with about 50% in excess of the normal working pressure

The discharge piping should be supported close to the pump flange to prevent vibration and strain on the pump casing. The velocity in the delivery pipe is usually 1.5 to 3.5 m/sec, generally about 2.5 m/sec.

A pressure gauge is fitted on the delivery side to indicate pressure during the working of pump.

The sluice valve on delivery side of the centrifugal pump must be closed when the pump is being started and till it build up pressure.

6.9. Capacity of Pumps

The capacity of pump 'Q' is the volume per unit time delivered by the pump. In metric measure, the units of capacity are litres per second (l/s) or cubic metres per second (m³/sec).

It is usual practice to design the pumping capacity of station in such a manner that some of the pump units can be run at all the times at a full capacity. Several pumps with various capacities can be installed depending upon the requirement of a particular situation such as demand, storage capacity available and the desirability of off peak pumping. By arranging pumps of different capacities, maximum efficiency and full economy can be achieved. It may be noted that total capacity has to be larger than maximum rate of demand so that in case of break down of any of the unit, the demand of water can be satisfied without overloading other units.

In case balancing storage is not available in the distribution system, the capacity of pump will have to be large enough to satisfy maximum rate of demand. Where balancing storage is available, pump can operate at average hourly rate of demand thus reducing the installed capacity.

The capacity would depend upon the restricted working hours also, either because of availability of power for restricted hours or for convenience and economy in case of small water supply scheme. In such cases the capacity shall have to be suitably increased.

In case there is no reserve storage capacity for fire, additional capacity of pumps shall have to be made to take care of emergency demand of water for fire.

Sometimes limitation of pump capacity is imposed by yield of source or the tube-well. Pumps are sized to deliver only the safe yield of the source. In case of a source being a stream etc., capacity of pump can be increased by arranging the storage of water from source.

The Manual on Water Supply, Govt. of India (Third Edition) May 1999 suggests two pumps (one duty and one standby) for small pumping systems of capacity less than 15 mld. Alternatively two duty and one standby, each of 50% capacity may be provided. In case of medium and large pumping stations, at least two standby pumps should be provided.

Pumps for Various Uses

Pumps find their application in variety of uses, such as coagulant feed pumps, back wash water pumps and booster pumps within the distribution system.

- a) **Coagulant Feed Pumps:** Pumps required to feed coagulants such as alum or ferric sulphates in solution are generally not of centrifugal type. Usually a constant level solution tank is used to maintain a constant head on the suction side of the pump. The capacity is the function of water supply pressure and frictional loss in the delivery lines. It is important to consult manufacturer's literature for making selection of coagulant feed pump to meet a particular
- b) **Back wash water pumps:** usually an elevated wash water tank of capacity large enough is provided for back washing of one filter bed at a time. The height of tank is maintained as necessary to provide required quantity of flow. For computing the head loss from back wash water tank through the filters, head loss in the filter under drains must be considered in addition to head loss in pipes, valves and fittings.

Some times back wash water pumps are used to feed water directly to back wash water piping system. The head of the pump required in this case would be that required to overcome all losses in under drains, filter bed, piping and the capacity of the pump would be equal to maximum rate of back wash. In such a case, standby provision is indispensable.

- c) **Booster pump within distribution:** Booster pumps are required to maintain a desirable pressure of 2.8 to 6.25 kg/cm², depending upon the requirement of a particular distribution system.

Sometimes in-line booster pump is installed directly connected to the pipe line. These boosters are of capacity to suit the capacity of incoming pipe and should be capable of generating additional head required to increase the pressure in the distribution system, to desirable extent. The pump shall be designed taking into consideration the pressure available on the suction side, static head, frictional head and the required residual pressure in the system.

Many water undertakings do not permit the use of in-line booster. In that case the booster pump takes suction from a storage reservoir and return higher pressure to the distribution system. Usually the

system is made automatic by providing pressure switch or float for automatic operation of starting or stopping the booster pump.

6.10. Choice for the Type of Pump and Selection of Pump

The type of pumping station and expected capacity and head are the major factors requiring attention for specific type of pump. In case of intake structures which are located in the surface reservoirs or where suction lift involved is beyond the limitations of centrifugal pump, vertical turbine pump with columns extending down into the suction well is a logical choice.

In case of suction conditions are within the limitation, the centrifugal pump would be the first choice. Other factors which deserve consideration for the selection of pump include the type and size of wells, fluctuation of draw down levels and location of the pump etc.

Pump with moving parts above the ground level are preferred because of easy maintenance. Where electrical energy is used, efficiency is of vital importance. It is more so when power is expensive. Instances are there when new pump installed to replace an old and an inefficient one, paid for itself in a very short time only by reducing the cost of energy consumed.

Pumps with flat characteristic curves are preferred because they allow for greater flexibility in service.

Centrifugal pumps are suited to operate under steady head and are not affected by turbid waters. The type and the material of impeller would depend upon the characteristics of water. For Clearwater closed type impellers are recommended. For turbid waters mixed flow impellers are suitable. The Details are shown in table 6.4.

TABLE: 6.4

Pump type	Suction-capacity to lift			Head range			Discharge range		
	Low 3.5m	Medium 6m	High 8.5m	Low upto 10m	Medium 10-40m	High Above 40m	Low upto 30L/s	Medium upto 500L/s	High Above 500L/s
Centrifugal horizontal end-suction	OK	OK	OK	OK	OK	No	OK	OK	No
Centrifugal horizontal axial split casing	OK	No	No	OK	OK	No	No	OK	OK
Centrifugal horizontal multistage	OK	OK	No	No	OK	OK	OK	OK	No
Jet-Centrifugal combinations	When limitations of suction lift are to be overcome			OK	OK	No	OK	No	No
Centrifugal vertical turbine	When suction lift is to be avoided			OK	OK	OK	OK	OK	OK
Centrifugal vertical submersible	When suction lift is to be avoided			OK	OK	OK	OK	OK	OK
Positive displacement pumps	Normally self priming			Limited only by the pressure which casing can withstand			OK	OK	No
							Easy adaptation for dosing or metering		

6.11. Installation of Pumps

The right type of foundation is most important for the success of any pumping installation. All pump installations require base plates and foundation blocks. The foundation block for the pumping unit is designed for (a) weight of the pumping unit, (b) weight of concrete foundation block, (c) area of foundation block (d) isolation of foundation block from the surrounding structure to absorb the vibration.

In order to meet the above requirements, the foundation block must be adequate in size and mass, rest on an adequate bearing surface, provide an accurately finished mounting surface and be provided with necessary anchor bolts. The size of the foundation concrete block and anchor bolts are generally supplied by the manufacturers of the pumping units.

The size of foundation block depends upon the dimensions and weight of the pumping unit. The following minimum standards are recommended.

- (a) Length and width of foundation block should exceed the length and width of the base plate of the equipment by minimum 15 cm on either side. The position of holding down bolts generally determines the width and length of the base.
- (b) The depth should be adequate to provide weight equal to 1.3 to 1.5 times the weight of the equipment and that there is sufficient depth to accommodate the holding down bolts properly. The weight of the foundation block should be sufficient to counter-act the sliding against horizontal thrust and to resist the uplift effect. The depth of the base must be such that the bottom is on satisfactory bearing stratum.
- (c) The area of the concrete block for machinery must be sufficient to spread the load on the ground without exceeding the safe bearing pressure. The centrifugal pump owing to common fabricated base plate and adequate holding down arrangements create vibration to nominal extent. When vibration is transmitted to ground, the bearing pressure considerably decreases in comparison to as generally assumed for the class of ground upon which the base bears.
- (d) The foundation anchor bolts used to hold the equipment in place should be of the material recommended by the manufacturer of the equipment. Anchor bolts are usually supplied by the manufacturer along with the equipment. The diameter of bolts is according to the mounting holes of the equipment. The length should be equivalent to minimum embedded length of 30 times the dia plus necessary length for J or L hook. An additional 14 to 15 cm length should be provided above the top surface of foundation for grouting sole plate, shims, equipment base washers and nuts, plus small variations in surface level of the foundation block. While laying the foundation block concrete, the location of holes is left in concrete, with the help of a sleeve of pipe or by some other suitable means to allow for adjustment required for the bolts to conform with mounting holes locations. The holes are filled in with concrete after fixing in position the pumping installation.
- (e) It is very important to isolate the foundation block of the equipment from the building structure because of vibrations. Cork rubber or lead sheet is used in case of heavier pumping installations. Manufacturer's instructions should be followed in respect of isolation materials. Cork or lead sheet is provided between the foundation block and the

lower soil. Isolation can be obtained by filling in sand between the foundation block and the side soil. For continuous vibration due to machinery, an allowance of 25% or more by increasing the total load should be made.

A single base should be provided under various supports of pumping machinery and sudden changes in depth and width should be avoided.

Chain Pulley Blocks and Over Head Cranes

For the installation, maintenance and repair of the heavy equipment, necessary provision of hoisting is required to be made in the pump house. Depending upon the requirement and the weight of different component of the machinery, simple spur gear pulley blocks with high tensile steel chains, single or double girder type, hand operated or power operated over-head cranes are provided for handling the equipment. Despite the increasing use of power operated over head cranes, there remain many situations where the use of hand operated crane is ideal either for economic or operational reasons.

a) Double Girder Type:

(Capacity 2 to 25 tons. Span 3 to 15.25m)

Heavy structural steel sections are bolted to fabricated steel end carriages to form a rigid and stable bridge structure. Four double flanged tram wheels carried on fixed axles carry the crane. Two of these tram wheels are given to provide the long travel motion, the effort being applied to a larger dia. Chain wheel keyed on to steel shaft spanning the full length of the crane bridge.

b) Single girder Type:

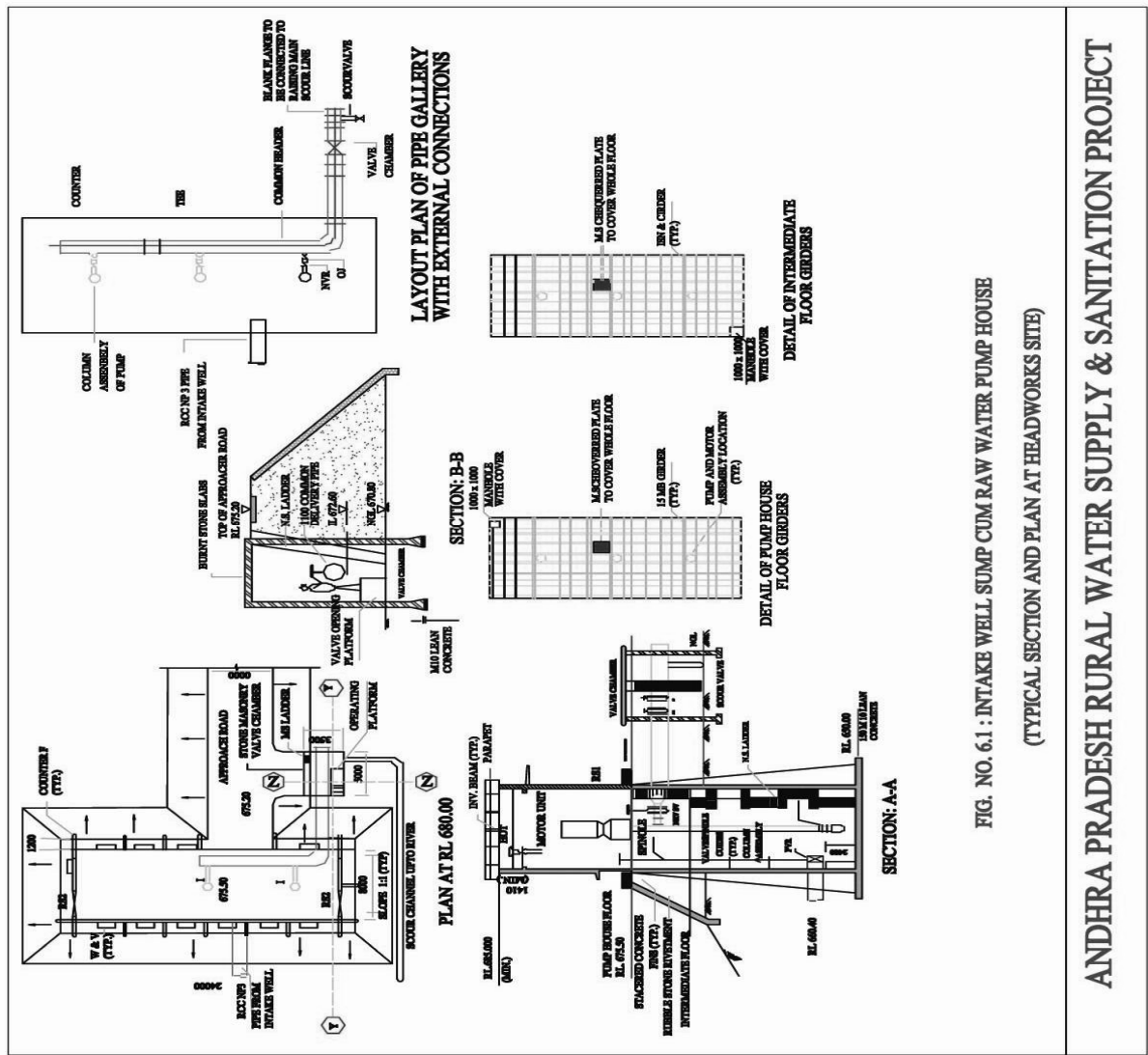
(Capacity 1/2 to 10 tons, span 3 to 15.25m)

The single Girder is basically similar in construction to the double girder crane, the two bridge girders being replaced by a single girder, with the hoisting unit built into a trolley which travels along the lower flange of the girder. The basic hoist unit is the worm gear pulley block which can be arranged for either push or hand gear travel.

Limitations on use of pumps

Do not run the pump:

- Well beyond the recommended range of the particular pump.
- Without lubricating the bearings with grease or oil, as the case may be
- With liquid other than specified
- With less NPSH than recommended
- With delivery valve completely closed for longer period.
- When misaligned
- Without lubricant to the stuffing box either internal or external
- Unless periodically checked
- When undue weight on suction and delivery side flanges
- Without proper priming
- When strainer is removed from suction



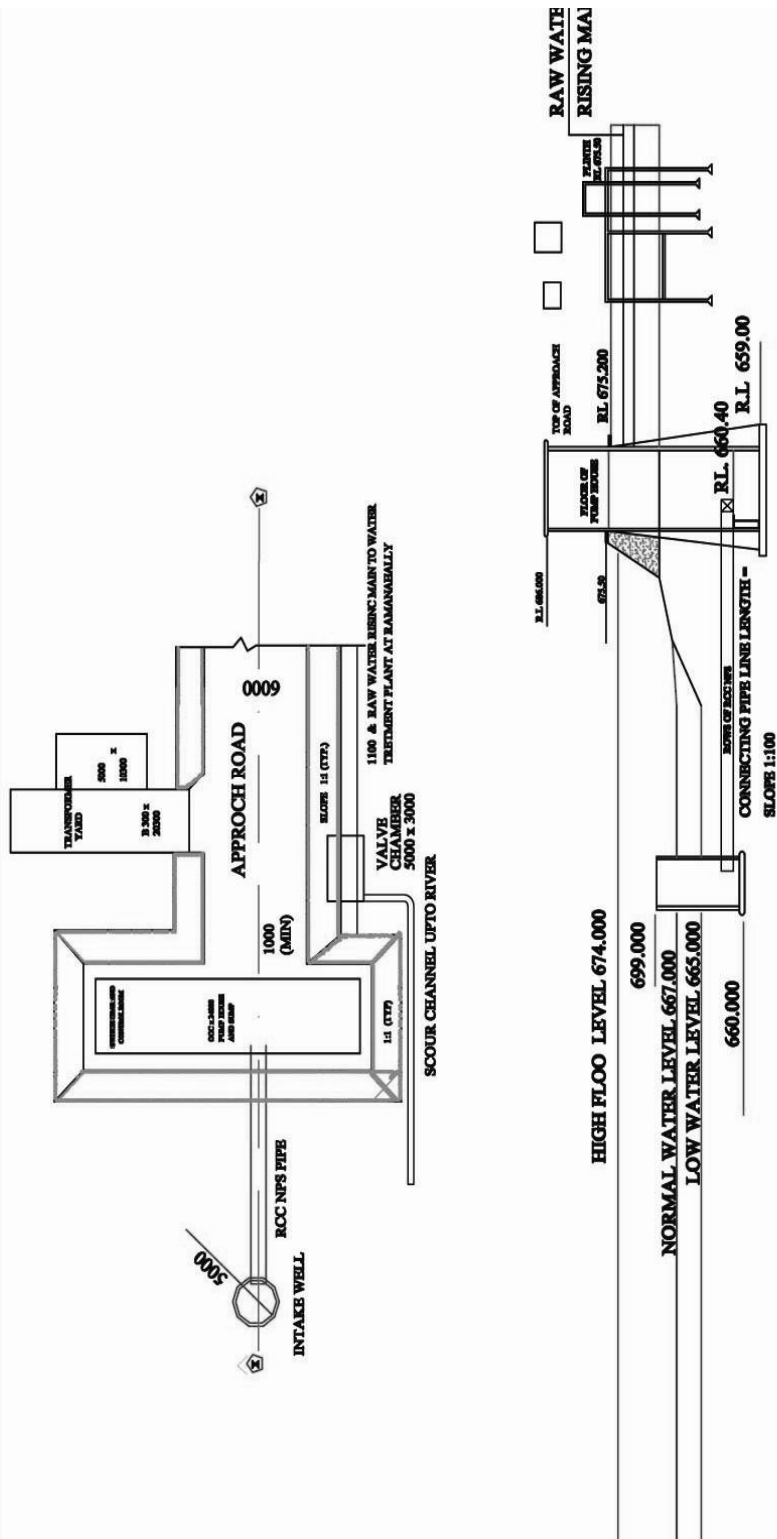
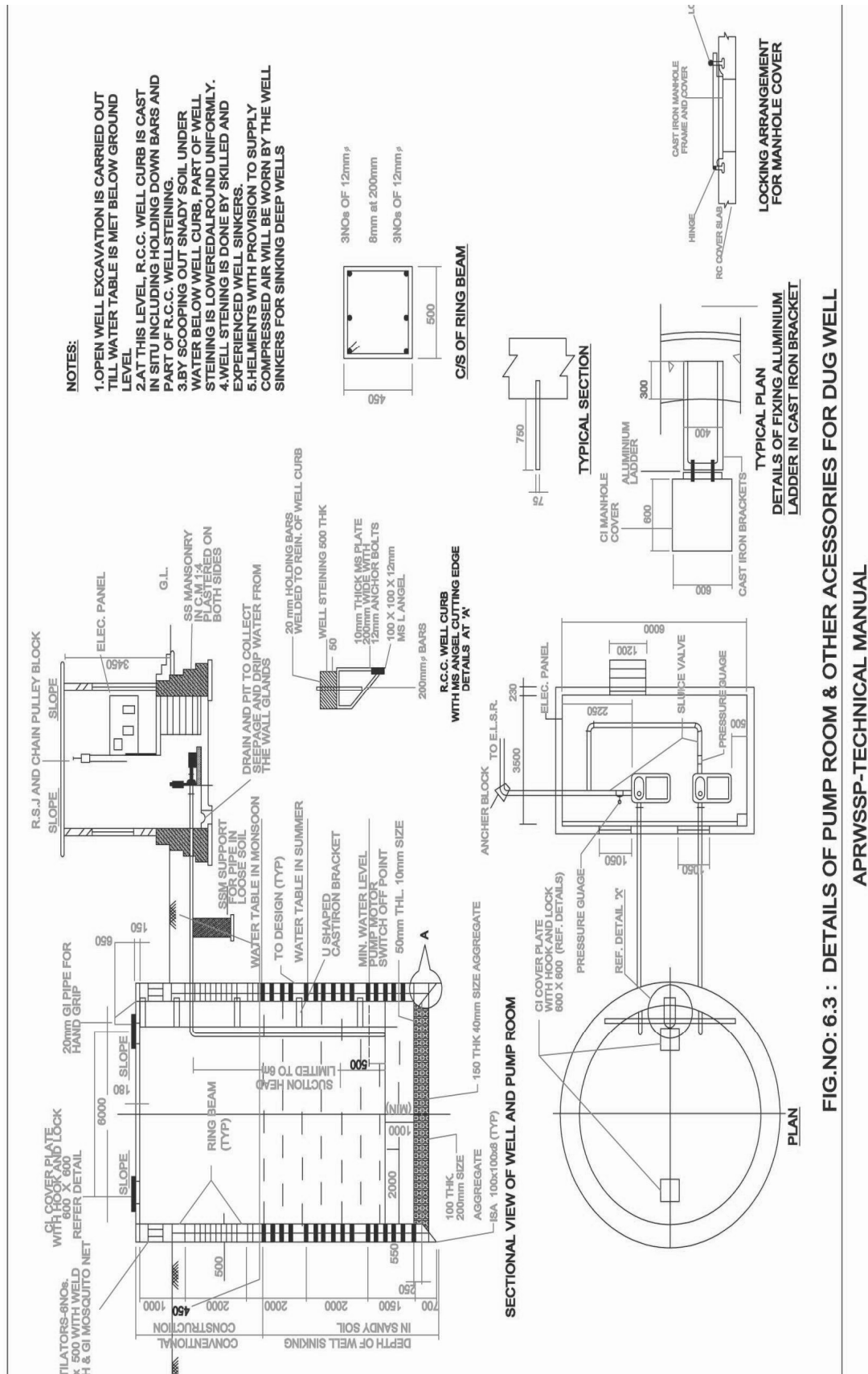
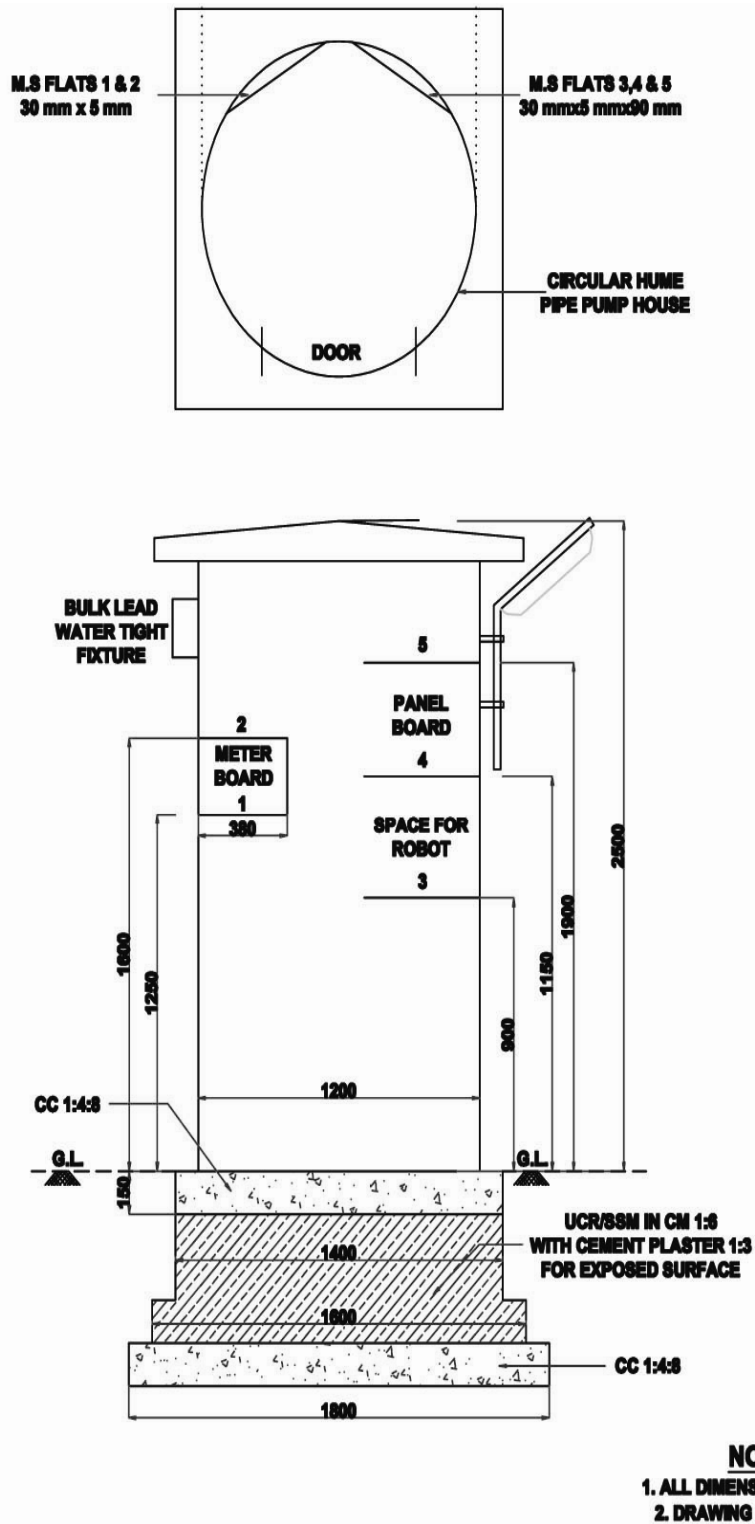


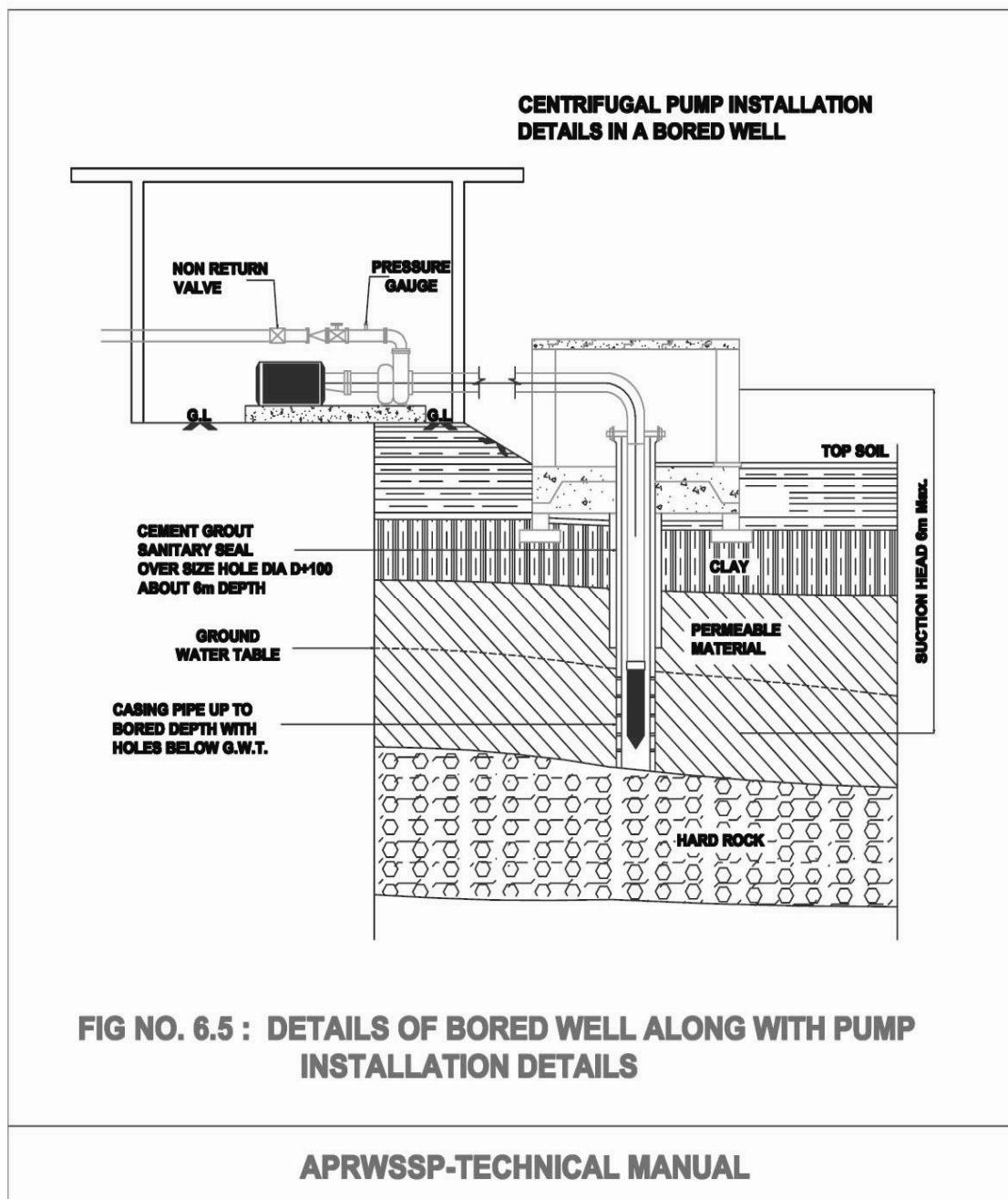
FIG . NO. 62: INTAKE WELL, JACK WELL CUM RAW WATER PUMP HOUSE
(TYPICAL SECTION AND PLAN AT HEADWORKS SITE)

ANDHRA PRADESH RURAL WATER SUPPLY & SANITATION PROJECT

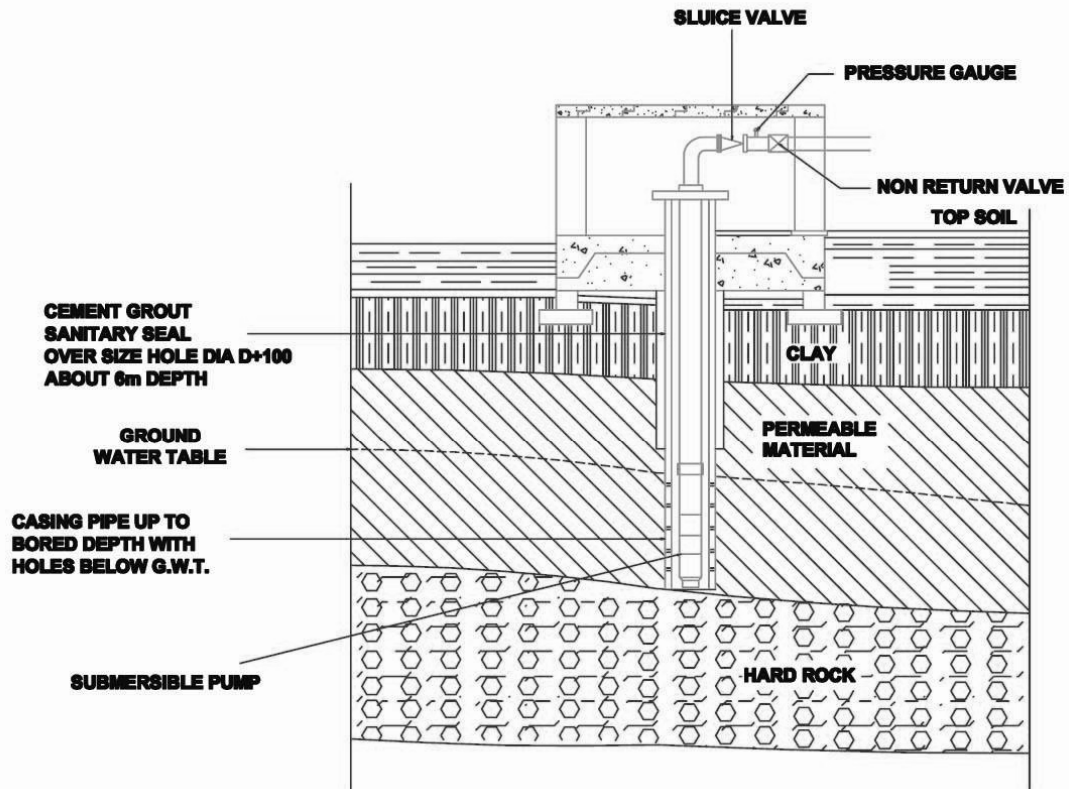




**Fig No. 6.4 :SKETCH SHOWING POSITION OF M.S.FLATS IN R.C.C
HUME PIPE PUMP HOUSES**



SUBMERSIBLE PUMP INSTALLATION DETAILS IN A BORED WELL



**FIG NO. 6.6 : DETAILS OF BORED WELL ALONG WITH PUMP
INSTALLATION DETAILS AS PER SITE CONDITION**

APRWSSP-TECHNICAL MANUAL

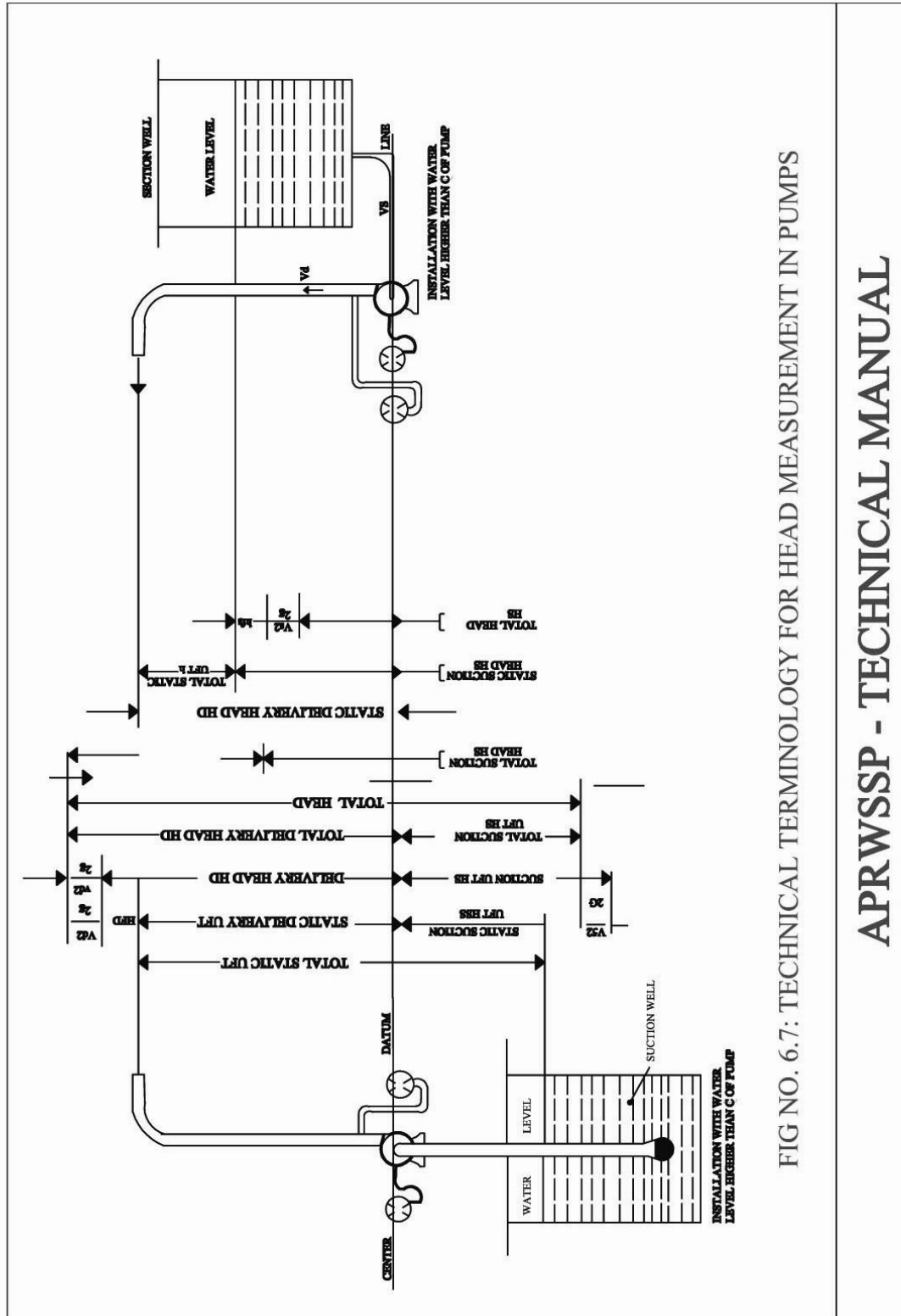


FIG NO. 6.7: TECHNICAL TERMINOLOGY FOR HEAD MEASUREMENT IN PUMPS

APRWSSP - TECHNICAL MANUAL

CHAPTER – 7

7. WATER TREATMENT

Treatment of water is one of the important functions executed in all water works. In this, different operations are carried out for making raw water obtained from various sources fit for use.

In Andhra Pradesh the ground water which is the main source of water supply to the villages is having quality problems. Most of the water is having excessive concentration of fluorides, TDS, hardness, nitrates and iron. Further there are instances of bacterial contamination. Where the water quantity and quality problems are severe and ground water cannot be relied upon the surface water with minimum treatment may be the only option. Normally ground water available does not require any extensive treatment and can be applied with disinfection alone. Fluorides, TDS and iron from ground water can not be removed easily as treatment plants for their removal require skilled operational personnel and constant attention apart from very high capital cost and O & M cost. Moreover, such treatment plants provided elsewhere for removal of fluorides have become non-functional. The presence of nitrate, in water is due to agricultural pollution and faecal pollution. There is no economical treatment method available for removal of nitrates in domestic water supply. Hence, it is suggested that the point of contamination of the source with nitrates shall be identified and remedial measures taken to prevent contamination rather than providing treatment process for removal of nitrates.

In view of the above facilities in treating contaminated ground water, it is proposed to provide surface water to the water quality and quantity affected villages. Surface water can be extracted either from infiltration gallery/infiltration wells or from canals, rivers, impounding reservoirs. Water from infiltration galleries does not require any treatment other than disinfection. However, in some instances surface water from the flowing streams, canals and ponds may be treated and supplied to the problem villages. Depending upon the turbidity of the surface water, whenever, the turbidity is more than 50 NTU it may not be amenable for plain sedimentation which may require chemical coagulation. Chemically settled water is not treatable in slow sand filters and hence when chemical coagulation is suggested rapid sand filters may be required. In view of the high capital cost and O & M cost and lack of skilled personnel for O & M, the rapid sand filters with chemical coagulation is recommended only in limited cases for treatment plants above 3 MLD for rural water supply systems.

7.1. Methods of Treatment and Flow sheets

The aim of water treatment is to produce and maintain water that is hygienically safe. The method of treatment to be employed depends on the nature of raw water constituents on the desired standards of water quality. The unit operations in water treatment include aeration, flocculation and clarification, filtration, disinfection, softening, deferrization, defluoridation and water conditioning and many different combinations of these to suit the requirements.

In the case of surface waters and ground waters, when the water has turbidity below 10 NTU plain disinfection by chlorination is adopted as shown in Fig. (a) & (b).

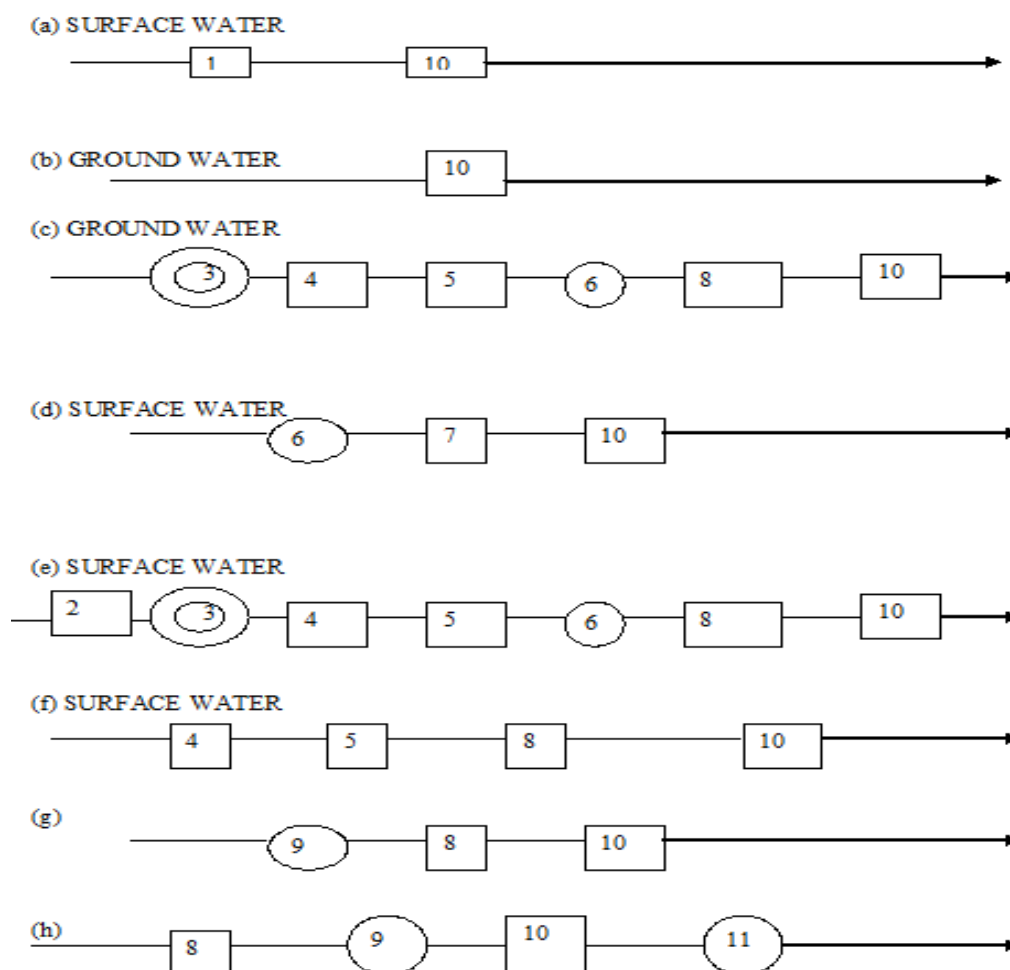
When the ground water contains excessive iron, dissolved carbon dioxide, aeration followed by flocculation (rapid and slow mixing) and sedimentation, rapid gravity or pressure filtration and disinfection may be necessary as in Fig (c).

In surface waters with turbidities not exceeding 50 NTU and where sufficient area is available, plain sedimentation followed by slow sand filtration and disinfection are practiced as shown in Fig (d).

Conventional treatment including pre-chlorination, aeration, flocculation (rapid and slow mixing) and sedimentation, rapid gravity filtration and post chlorination are adopted for highly polluted surface waters laden with algae or other microorganisms as shown in fig (e).

Sometimes, unconventional flow sheets may be adopted for waters of low turbidity (below 1 to 15 NTU) and containing low concentration of suspended matter as in Fig (f).

Water with excessive hardness needs softening as in Fig. (g). For removal of dissolved solids, demineralization by ion exchange may form a part of the domestic or industrial as in Fig. (h).



1. STORAGE
2. CHLORINATION (PRE)
3. AERATION
4. RAPID MIXING
5. FLOCCULATION – SLOW MIXING

6. SEDIMENTATION
7. SLOW SAND FILTRATION
8. RAPID SAND FILTRATION
9. SOFTENING
10. CHLORINATION (POST)
11. DEMINERALISATION

Methods of purification of water:

- Screening
- Aeration
- Plain sedimentation

-
- Sedimentation aided with coagulation
 - Filtration
 - Disinfection
 - Softening

UNIT OPERATIONS IN WATER TREATMENT

7.2. Screening

Screens are generally provided in front of the pumps or the intake works, so as to exclude the large size particles such as debris, trees, animals, bushes etc. Coarse and fine screens are to be provided for better result. While designing screens clear opening should be provided. The materials which are deposited on upstream of screen should be removed regularly manually or mechanically

7.3. Aeration

It is the process of bringing water in intimate contact with air, while doing so the water absorbs oxygen from the air. The carbon dioxide gas is also removed up to 70% and up to certain extent bacteria is also killed. Iron, manganese and H_2S gas are also removed up to certain extent from the water.

The various methods of aeration are

- By air diffusion. In this method perforated pipes are fixed in the bottom of the settling tanks. The compressed air is blown through the pipes which comes out in the form of bubbles and stirs the whole water at greater speed. During the upward movement of the air, it is thoroughly mixed with the water and does its aeration. The aeration tanks are usually made 2.5 to 3.0m deep and work on the principle of continuous flow, having minimum detention period of 15 minutes (at the average flow). The quantity of air consumed varies from 0.3 to 0.6 cu.m. per 1000 litres of water.
- By trickling beds. In this method the water is allowed to flow on the trickling beds of coke which are supported on the perforated bottoms of the trays. The water is allowed to trickle from the top to the bottom under gravitational force. During this downward movement, the water gets mixed up with the air and the aeration takes place. The size of the coke tray ranges between 50 and 75 cm. The efficiency of this method is more than 'cascades', but it is less effective than the method of spray 'nozzles'.
- By using spray nozzles: In this method the water is blown up in the air into the fine sprays to a height of 2 to 2.5 m under water pressure of 0.7 to 11.5 kg/cm². When small particles of water come in contact of greater surface area of the air, they absorb it and the water is aerated. The dissolved gases like H_2S , CO_2 etc. escape into the atmosphere and the oxidation of various substances and organic matter takes place.

By using cascades: In this method the water is allowed to fall over a series of concrete steps or over a weir etc. in thin film. During the fall, the water gets thoroughly mixed with the atmosphere air and gets aerated.

7.4. Plain Sedimentation

Plain sedimentation is required from one to several days without subsequent filtration. Where chemicals are introduced to hasten the process of settling, the addition of chemical is called

‘Coagulation’. The process of addition of chemicals to separate the dissolved impurities out of solution is known as ‘Chemical Precipitation’ and the sedimentation process after the addition of chemicals is described as ‘Sedimentation’ or ‘Post Sedimentation’.

Plain sedimentation has little effect in removing small suspended particles in water. The larger and heavier particles, however, settle depending upon their size and the velocity of flow in water. River or stream waters with heavy loads of silt even up to 5000 PPM during rainy season are subjected to sedimentation both before and after coagulation or precipitation.

Much longer settling time is required for basins preceding slow sand filters than for rapid sand filters. Rectangular tanks have lengths commonly up to 30 m but larger lengths up to 100 m have also been adopted. Schematic diagrams of various types of clarifiers and settling tanks are shown in Fig. 7.1, 7.2, 7.3 & 7.4.

The factors influencing the sedimentation process are:

- (1) Size, shape and weight of floc
- (2) Viscosity and temperature of water
- (3) Effective average period available for sedimentation (Detention period)
- (4) Effective depth of tank
- (5) Surface area
- (6) Surface over flow rate.
- (7) Velocity of flow
- (8) Inlet and outlet design

Sedimentation Rates of Various Materials (Table 7.1)

Sl.No	Type of Material	Dia in mm	Rate of Settlement (m/h)
1	Coarse sand	1.0	365.75
		0.5	193.84
2	Fine sand	0.25	97.53
		0.10	29.26
3	Silt	0.05	10.61
		0.005	0.14
4	Fine clay	0.001	0.005
		0.0001	0.00005

- (1) It is necessary to study the characteristics and nature of the suspended matter present in the raw water.
- (2) Viscosity and Temperature of Water : Viscosity of water has definite influence on the efficiency of settling process. The rate of sedimentation of water at 30 C temperatures is 2.3 times more than that at 0°C temperature. It is, therefore, necessary to keep this influence in view while designing the settling tanks intended to handle cold waters.
- (3) Effective average period available for sedimentation: The detention period of tank is the time that is needed for the flow of water to fill the tank if there were no outlet flow. Thus, if a normal flow is 20 m³/hour and the capacity of tank is 80 m³, the detention period will be 80/20=4 hours.

Undue importance should not be given to theoretical detention period, because the inlet and outlet arrangements, the length to width ratio and depth of basin determine the effective flow through period, which is usually considerably shorter than the theoretical detention period.

Water does not pass through the sedimentation tank as a uniform mass. The incoming current displaces water already present in the tank and thus produces complex currents and eddies. This can be observed by adding a dye or salt for a brief period to the influent and observing the distribution of material. Flow through period is the average effective period. The efficiency of sedimentation tank is established by the ratio of the observed flow through period and theoretical detention period. This ratio is known as the 'Efficiency of displacement'.

Efficiency of displacement = Flow through period/detention period X 100

The following are the guides for the evaluation of displacement efficiencies.

Ideal tanks	=63% efficient
Good tanks	=30% to 50% efficient
Poor tanks	=5% to 30% efficient

The detention period should be at least 4 hours and should be based on the maximum capacity of tank, so that factor of safety is provided for period of poor flocculation. Efficiency should be greater than 30%.

For coagulated waters the detention period may be 2 to 2 ½ hours while for vertical flow (Hopper bottom) tanks, the detention period used is 1 to 1 ½ hours. Settling tanks should be capable of giving settled water having turbidity not exceeding 20 NTU and preferably less than 10 N.T.U.

- (4) Effective depth of tank: The capacity of tank is the area multiplied by depth. Area is much more important than depth. In practice tanks with 4 hours detention period are provided with a depth ranging from 2.5 m to 5.0 m with 3.0 m being a preferred value, over the sludge deposit zone. A total depth of 3.6 m is common.
- (5) Surface Area: The elimination of particles of various sizes is a function of the surface area and it is independent of the depth of the tank. The depth is significant only for providing sludge storage space and maintaining the velocity of the overlying flowing water below scouring limits. Settling floc must be deposited from the flowing water before water reaches the effluent end of the tank. The narrower the tank the less chance there is for setting up of cross current and eddies due to wind action.
- (6) Surface Overflow rate or Surface Loading: Surface loading is expressed in unit volume per unit area per day. This rate should suit the characteristics and specific gravity of the particles intended to be settled. Cox recommends that surface overflow rate should not exceed 36 m³/m²/day, in horizontal flow tanks. In vertical flow settling tanks the CPHEEO Manual recommends 40 to 50 m³/m²/day. In practice factor of safety should be provided by selecting lower rates.
- (7) Velocity of Flow: The average flow through velocity in horizontal flow through rectangular tanks is usually kept between 0.5 to 1.5 cm/sec.
- (8) Inlet and Outlet design: Inlet is designed and proportioned in such a manner that the flocculated water does not get unduly agitated because of turbulence or weir action.

The influent channel or conduit should be so designed as to provide a velocity not greater than 0.45 m/sec. The influent pipe should deliver water behind perforated baffle or into a perforated trough so that incoming water is evenly distributed throughout the width of the tank. Baffles are extended for two-third depth, so as to divert the influent to the lowest one-third of the tank depth. This baffle should be about 1 m to 3 m from the inlet end to suit the size of the tank.

In very large tanks where depth is necessarily great it may be advisable to provide longitudinal baffles to confine the flow to straight channels.

The outlet is provided as an overflow weir which should be minimum equal to the width of effluent end of the tank. The weir should have adequate total length to provide a weir loading between 100 to 300 m³/m/day, as recommended by Cox. But when settling tanks are properly designed, well clarified waters can be obtained at weir loading of even upto 1500 m³/m/day.

7.5. Sedimentation with Coagulation and Flocculation

The Terms 'Coagulation' and 'Flocculation' are often used indiscriminately to describe the process of removal of turbidity caused by fine suspensions, colloids and organic colour. 'Coagulation' describes the effect produced by the addition of a chemical to a colloidal dispersion, resulting in particle destabilization. Operationally, this is achieved by the addition of appropriate chemical and rapid intense mixing for obtaining uniform dispersion of the chemical. 'Flocculation' is the second stage of the formation of settleable particles (or flocs) from destabilized colloidal seized particles and is achieved by gentle and prolonged mixing.

Very fine suspended mud particles and the colloidal matter present in water cannot settle down in plain sedimentation tanks of ordinary detention periods. They can, however, be removed easily by increasing their size by changing them into flocculated particles. For this purpose, certain chemical compounds called coagulants are added to the water, which on thorough mixing, form a gelatinous precipitate called 'floc'. The very fine mud particles and the colloidal matter present in water get attracted and absorbed in these flocs, forming the bigger sized flocculated particles. The process of addition and mixing of the chemicals (i.e. the coagulants) is called the coagulation. The coagulated water is then made to pass through the sedimentation tanks, where the flocculated particles settle down, and are, thus, removed. The use of coagulants is generally necessary for clarifying raw waters containing turbidity greater than 30 to 50 mg/l, but in actual practice, plain sedimentation is rarely used these days, and the coagulation before sedimentation is almost universally adopted in all the major water treatment plants.

Coagulant Dosage

Although there is some relation between turbidity of the raw water and the proper coagulant dosage, the exact quantity can be determined only by trial. Even thus determined, the amount will vary with other factors such as time of mixing and water temperature. The use of the minimum quantity of coagulant determined to be effective in producing good flocculation in any given water, will usually require a fairly long stirring periods varying from 15 to 30 minutes in summer and 30 to 60 minutes in the colder months, as water temperatures approach the freezing point.

Addition of coagulants in excess of the determined minimum quantity may increase bactericidal efficiency. It is, however, usually more economical to use the minimum quantity of coagulant and to depend on disinfectant for bacterial safety.

Very finely divided suspended matter is more difficult to coagulate than coarse particles, necessitating a large quantity of coagulant for a given turbidity. The cation-exchange capacity of the particles of turbidity bears a significant relationship to the success of flocculation.

Choice of Coagulant

In selecting the best coagulant for any specific treatment problem, a choice has to be made from among various chemicals, each of which may offer specified advantages under different conditions.

The common coagulants used in water works practice are salts of aluminium viz. filter alum, sodium aluminate and liquid alum and iron salts like ferrous sulphate (Copperas), ferric sulphate, ferric chloride.

Selection of aluminium or iron coagulants is largely decided by the suitability of either type and its easy availability. Both filter alum and ferric sulphate have certain specific advantages. Alum does not cause the unsightly reddish brown staining of floors, walls and ferric form of iron salts. The dissolving of ferric sulphate also offers difficulties not encountered with alum. The trivalent aluminium iron is not reduced to a more soluble bivalent iron, as may be the case when ferric salts are used with waters high in organic matter. On the other hand, ferric floc is denser than alum floc and is more completely precipitated over a wider pH range. Also good flocculation with alum is not possible in some waters.

The choice of the coagulant to be used for any particular water should preferably be based upon a series of jar tests, so planned that it will permit accurate comparison of the materials being, studied under identical experimental conditions. The coagulant dose in the field should be judiciously controlled in the light of the jar test values.

7.5.1. Types of sedimentation tanks

The three types of sedimentation tanks are:

1. Rectangular tanks
2. Circular tanks
3. Hopper bottom tanks

1) **Rectangular tanks:** These are rectangular in plan and consist of large number of baffle walls. The function of baffle walls is to reduce the velocity of incoming water to increase the effective length of travel of the particle and prevent the short-circuiting. These tanks are generally provided with channel type inlet and outlet extending on the full width. The floor between two baffles is made like a hopper sloping towards centre where sludge-pipe is provided. The sludge is taken out through sludge outlet under hydrostatic force by operating the gate-valve.

2) **Circular tanks:** These are generally not used in plain sedimentation, but are mostly used in sedimentation with coagulation. There are two types of circular sedimentation tanks classified on the basis of flow of water inside it.

- a) Radial flow circular tank: The water enters in this tank through the central inlet pipe placed inside the deflector box. The deflector box deflects the water downwards and then it goes out through the holes provided in the bottom sides of the deflector box. The water flows radially from the deflector box towards the circumference of the tank, where an outlet is provided on the full periphery. All the suspended particles settle downward on the sloppy floor and clear water goes through the outlet. The sludge is removed on the story floor and clear water goes through the outlet. The sludge is removed by scrapper (known as raking arm), which continuously moves around the floor at a very small velocity. The maximum velocity of raking arm does not exceed 4.5 metres/hour.
- b) Circumferential flow circular tank. Water enters in the tank through two or three vertical slits. There is one rotating arm in the tank, which allows the water to move along the circumference of the tank. Water while moving at very low

velocity allows its suspended impurities to settle in the tank, which can be removed from sludge outlet. The clear water is drawn over a small weir type outlet .

- 3) **Hopper bottom tanks:** These are vertical flow tanks, because water flows upward and downward in these tanks. The water enters in these tanks from the top into deflector box. After flowing downwards inside the deflector box the water reserves its direction and starts flowing upward around the deflector box. The suspended particles having specific gravity more than one, cannot follow the water at the time of reversing its direction, and settle in the bottom, from where they are removed through sludge outlet pipe under hydrostatic pressure. Rows of decanting channels are provided at the top to collect the clear water. The water after flowing in the channel is taken out from the outlet channel provided on one side of the tank. These tanks are mostly used in sedimentation with coagulation process. The schematic diagram of Hopper bottom settling tank is shown in fig.7.5.

7.5.2. Design parameters of sedimentation tanks

The design parameters recommended by the Manual on Water Supply and Treatment, CPHEEO, Govt.of India, III Edition May 1999 and WHO Operation and Control of Water Treatment Process by Cox are summarized below:

- 1) Detention Period:
 - a. Plain sedimentation tanks = 3.0 to 4 hours
 - b. Coagulated waters = 2 to 2.5 hours
 - c. Vertical Flow (up flow) clarifier= 1 to 1.5 hours
- 2) No. of Units = 2 or more (one as standby)
- 3) Depth of tank = 3m (2.5 to 5.0 m)
- 4) Velocity of flow = 0.3m/sec (0.2 to 0.3)
- 5) Surface loading:
 - a. Horizontal flow circular=36 m³/m²/day (30 to 40 m³/m²/d)
 - b. Vertical flow =40 to 50 m³/m²/d
 - c. Plain sedimentation =15-30 m³/m²/d
- 6) Extra capacity of storage of sludge = 25%
- 7) Weir loading =100 to 300 m³/m/day.
(upto 1500 m³/m/day in well designed tanks)
- 8) Floor slope
 - a. 1 in 12 or 8% for mechanically scrapped circular and square tanks.
 - b. 1 in 100 or 1% for mechanically scrapped rectangular tanks.
 - c. 1 in 10 or 10% for manual cleaning.
- 9) Length to width ratio = 3:1 to 5:1
- 10) Slope for sludge without mechanical scrappers = 1.2:1 to 2:1 (Vertical: Horizontal)
- 11) 90° V Notch Weirs = about 5 cm deep, 15 to 30 cm apart on centre.
- 12) Distance between paddle tips = 1m
- 13) Paddle tips above the floor level = 2 to 3 cm
- 14) Clearance between top of scraper and tank of wall = not exceeding 15 cm.
- 15) Paddle area =10 to 20% of the area swept by paddles.

-
- | | |
|--|--|
| 16) Scraper Velocity | =one revolution in 30 to 40 minutes or tip velocity of scraper 0.3 cm/sec or below |
| 17) Velocity of water in outlet conduit | =not more than 0.4 m/sec. |
| 18) Power requirement for scraping arrangement | =about 0.75 KW/m ² of tank area. |
| 19) Sludge removal pipe: | |
| a. Non mechanized unit | =200 mm or more |
| b. Mechanised unit with continuous removal of sludge with hydrostatic head | =100-200mm |

Generally the sludge is removed from tank through pipes under hydrostatic pressure. The units which are not mechanized, 200 mm dia or larger dia pipes are provided for sludge removal. For mechanized units 100 to 150 mm dia pipe are used for continuous removal process under hydrostatic head. The circular tanks which are equipped with revolving bridge with scrapers, floors slopes are 1 in 12 and in case of manual cleaning, 1 in 10 slopes should be provided.

7.6. Flocculation Equipment

This is an operation by which the coagulant is distributed through out the body of water rapidly and uniformly. The operation is generally termed as 'Flash Mixing'. This process helps in formation of microflocs, coagulants are properly utilized, prevents localized effects of chemicals and other effects which lead to less effective utilization of coagulants. The turbulence for achieving the rapid mixing is provided by for several methods such as aerators, weirs, spiral flow tanks and channels provided with baffles. Sometimes low lift centrifugal pumps are used for this purpose but the use of pump does not prove to be effective enough to serve as flash mixer. Schematic diagrams of various flocculators are shown in Fig. 7.6, 7.7, 7.8, 7.9

The CPHEEEEO Manual recommends that where head loss through the plant is to be conserved and where flow exceeds 300 m³/hr, mechanical mixing known as flash mixing is desirable. Multiple units may be provided for large plants. A detention time of 30 to 60 seconds is recommended in flash mixing. Head loss of 20 to 60 cm of water is usually required for efficient mixing.

(A) Gravitational or Hydraulic Mixing

(1) Hydraulic Jump Mixer: The arrangement of hydraulic jump mixer consists of combination of a chute followed by a channel with or without sill. Super critical velocity i.e. 3 to 4 m/s is created by the chute and the channel with a gentle slope induces the jump. These flumes constructed for the purpose of measurement of flow in the water works system can also be used in which the hydraulic jump occurs at the throat of the flume. The loss of head in hydraulic jump mixing is to the extent of 30 cm to 60 cm. In case of large plants this arrangement of measuring device can be used as a standby to mechanical mixers. For small plants this can directly serve the purpose. Overflow weirs have also been used for rapid mix. A head loss of 0.3 m to 0.6 m across the weir has been reported.

(2) Other Mixing and Stirring Devices: Several methods are adopted to obtain rapid mixing. At a point down stream of weir where there is sudden drop in water level causes turbulence and channels can be added at this point. Where venturi or an orifice is located in the pressure pipe, chemicals are added upstream from this point. Mixing can be obtained by adding chemical in suction or delivery of the low lift pumps i.e. at the points where maximum

turbulence is there. Although rapid mixing is obtained from all these methods but effective control is not possible.

- (3) Baffled Channels of Basins: In this type of arrangement, agitation is obtained by providing 'over and under' and 'around the end' baffles. Water flows through these baffles and turbulence effect is achieved by rapid mixing. The extent of mixing depends on the distance between the baffles, total flow and the length of the channel. In this system considerable loss of head occurs due to friction at each point of turbulence. The baffles can be made of 75 mm thick reinforced cement concrete, brick or stone masonry rendered smooth. It is necessary to make adequate arrangement for scouring around the end type channels because lot of deposits takes place in the channel. To permit cleaning, the distance between the baffles should not be less than 45 cm. The basis of design is the same whether around-the-end-baffles or over-and-under-baffles.

This system has many advantages of being simple and free from short circuiting and no mechanical equipment is needed. The system, however, involves a considerable loss of head and does not provide any flexibility. Often more coagulant is required to obtain good flow owing to less efficient mixing than can be obtained in mechanical mixer.

The velocity gradient 'G' is computed with the help of the following equation:

$G = 313 \sqrt{h/MT}$ where

h = Loss of head due to friction and bends, in cm.

T = Detention time in seconds.

G = Velocity gradient, 1/second,(cm/sec/cm)

M = Absolute viscosity, centipoises (10^{-2} gm/cm.sec)

The detention time may range between 10 to 30 minutes. Higher velocities are preferable to obtain more turbulence and avoid deposits in the channel. The head loss generally varies between 15 and 60 cm. These design parameters decide the cross sectional area of flow for velocity of 0.6 m/s, neglecting the baffles. The clear space between the wall and the end of each baffle should be approximately 1.5 times the distance between baffles, but it must not be less than 60 cm.

The loss of head in bends for each 180° bend for round the end type can be computed as 2 to 3.5 times the velocity head with the help of the following equation.

$H = 3.5 V^2/2g$ where

H = Total head loss in metres

V = Velocity of flow in the channel, m/s

G = Acceleration of gravity, $9.81 \text{ m}^2/\text{sec}$.

It is not desirable to keep depth less than 0.90m. Where the calculated depth works out less than this in case of around the end baffle system because of likely considerable variation in the flow velocity even with a little change in water depth. The required depth is obtained by dividing the desired cross sectional area of each channel by the distance between the baffles. A minimum free board of 150 mm is normally provided.

In case of baffle arrangement of 'over and under' type, the required width of basin can be calculated by dividing the required cross sectional area of each channel by the spacing selected for providing baffles. The distance between baffles is not less than 0.45 m. The depth usually is kept 2 to 3 times the

spacing between the baffles. The distance between the top of the baffle and surface of water or between the bottom edge of the baffle and bed of the channel is maintained at about 1.5 to 3.0 times the space between the baffle walls. Velocity is in the range of 0.1-0.25 m/s. Detention time is between 10-20 minutes.

- (4) Pipe Flocculators: When long length of raw water mains are available, coagulants are introduced at the upstream end by providing venturi throat. For effective flocculation, a stretch of about 3 to 8 K.M. long pipe is essential. The system encounters heavy frictional losses on account of floating flocculent deposits on the sides of pipe wall.

- (B) Mechanical Mixers: The CPHEEO Manual recommends direct mixing by pumps for small plants of capacity up to 200 m³/hour and flash mixing where flow exceeds 300 m³/hr.

Mechanical stirring devices (Flash Mixers) are found most satisfactory and are thus being used at all newly constructed plants. This system has several advantages over basins provided with baffle walls such as less initial cost, more flexibility in operation and with least head loss, generally of the order of 0.4 to 1.0 m.

The impellers used in mechanical mixing cause effective turbulence. In this type of system revolving paddles with horizontal or vertical shaft are suspended from horizontal beam which move up and down, driven by a speed reducing motor. The arrangement is further made more effective by providing stationary blades within the unit that oppose the rotational movement of the entire body of water. The multiple speed motors have the advantage of meeting variable flow requirements.

Total area of paddles generally range between 10-25% of the area swept by their movement. The maximum peripheral speed should be about 0.6 m/s so as to provide sufficient range of speed below this value. Where plants are large it is advisable to have more than one unit in series in order to reduce the chances of short circuiting. A detention time of 30 to 60 second is provided. Ratio of tank height to dia of 1:1 to 3:1 is preferred for proper dispersal. Paddle to be epoxy painted and shaft to be of EN9 steel.

Design Criteria for Flash Mixer

The design criteria for flash mixer are summarized as under:

- | | |
|---|--|
| (1) Detention time | : 30 to 60 seconds |
| (2) Velocity of flow | : 0.9 m/sec |
| (3) Depth | : 1 to 3 m |
| (4) R.P.M of blades | : 100 (paddle type) 400-1400(Propeller type) |
| (5) Power requirement | : 0.041 K.W per 1000 m ³ /day |
| (6) Ratio if impeller dia to tank dia | : 0.2 to 0.4 |
| (7) Ratio of tank height to dia meter | : 1:1 to 3:1 |
| (8) Loss of Head | : 0.4 to 1.0 m |
| (9) Hydraulic-partial flume type super critical velocity in chute | : 2 – 4 m/sec. |

- (C) Flocculation: After flash mixing i.e. after achieving the effective agitation to mix the coagulant, subsequent flocculation process requires controlled agitation with a velocity of flow or speed of the paddles ranging from 0.2 to 0.6 m/sec. velocity below 0.1 m/sec allows the sedimentation of the flow when it should be in suspension whereas velocities over 0.6 m/sec will avoid the growth of readily setting flow.

Generally best results are achieved with velocities ranging between 0.3 to 0.4 m/sec. Turbid waters, however need higher velocities whereas colored waters or water with low turbidity require lower velocities.

Design for Flocculator

(1) Depth of tank	: 3.0 to 4.5 m
(2) Detention time	: 10 to 40 min, normally 30 min, (30 to 60 min. in colder months when water reaches freezing point)
(3) Velocity of flow	: 0.2 to 0.8 m/sec, normally 0.4 m/sec
(4) Total paddle area	: 10 to 25 % of cross-sectional area of tank
(5) Peripheral velocity of blades	: 0.2 to 0.6 m/sec
(6) Recommended range for best Performance	: 0.3 to 0.4 m/sec
(7) Position of paddle	: Paddle tip to be 2 to 3 cm above the floor level and below the water surface
(8) Distance between paddle tip	: 1 m
(9) Range of velocity	: $G = 10$ to 75 sec^{-1} gradient
(10) Range of dimensionless factor	: $Gxt = 10^4$ to 10^5 where (t = time of flocculation)
(11) Power consumption	: 10.0 to 36.0 KW/mld

Pebble Bed Flocculator: The pebble bed flocculator contains pebbles of sizes ranging from 1 mm to 50 mm smaller the size of the pebbles, better is the efficiency, but faster is the build up of the head loss and vice versa. The depth of the flocculators is between 0.3 to 1.0 m.

The velocity gradient is given by:

$$G = [(Pg\theta h_f)/(\alpha\mu A)]^{1/2}$$

Where

- h_f = Head loss across the bed (m)
- α = Porosity of bed
- A = Area of flocculator (m^2) and
- L = Length of bed (m)

The main advantage of pebble bed flocculator is that it requires no mechanical device and electrical power. The operation and maintenance cost is very low. The drawback of this flocculator is that there is gradual build up of the head loss across the pebble bed and therefore needs periodical cleaning.

Practical Hint on flocculation System: The process of flocculation should be continued for a period of 20 to 30 minutes and sometimes for longer periods. If the period is prolonged, usually the dose of coagulant required is less. With more time of flocculation, lower degree of agitation can do and vice versa.

The temperature has an important effect on the chemical action taking place in the flocculation process. Longer period of flocculation is required for water with lower temperature or heavy doses of chemicals are required.

The process of flocculation proves ineffective if correct dose of chemicals are not used and effective methods of flocculation are not adopted. Complete effect at various stages of the process should be observed by carrying out jar test remembering that the effective pH range with alum is 5.5 to 8.0.

In case of cold water and formation of small floc which do not settle effectively it is advisable to use silica with alum. Since, this is a sensitive process, it requires skilled staff. It is generally observed that the chemical doses found effective in the plant are slightly lower than the chemical doses found effective in the plant are slightly lower than with the jar test. Another difficulty which is generally experienced is that good result seen in tests, are not found in the plant performance. This is for the obvious reason that the controlled and favorable degree of agitation and time for flocculation cannot be maintained so precisely in the plant. This trouble is usually encountered with the old plants. In order to surmount this difficulty an approximate degree of agitation and detention period can be determined by observing a small piece of paper thrown into the water. Accordingly the same amount of agitation can be adjusted in the jar test in the laboratory.

The observation of floc formation in the water is a must for proper supervision and control of flocculation process. The formation of flocs can be observed in flocculator and settlement in clarifier during sun shine. Submerged lights with shade near the outlet of flocculator and clarifier at depth of 1.5 to 1.8 m can be provided for the purpose which can be illuminated at the time of observation.

7.7. Filtration

Screening and sedimentation removes a large percentage of the suspended solids and organic matter present in raw supplies. The percentage of removal of the fine colloidal matter increases when coagulants are also used before sedimentation. But however, the resultant water will not be pure, and may contain some very fine suspended particles and bacteria present in it. To remove or to reduce the remaining impurities still further, and to produce potable and palatable water, the water is filtered through the beds of fine granular material, such as sands etc. The process of passing the water through the beds of such granular materials called as filters, is known as filtration.

Filtration may help in removing colour, odour, turbidity, and pathogenic bacteria from the water. Very fine and colloidal particles of un-settable nature cannot be removed in sedimentation process alone. Water coming out of settling tanks and clarifiers is fit for filtration. In the process the water from sedimentation tank is allowed to pass through a bed of sand and the filtrate is collected at the bottom through the under drains. The action of filtration through the filter media retains finer and colloidal particles of silt and clay. The filters are periodically washed and put to use again.

The two types of filters are

- Slow sand gravity filters; and
- Rapid sand gravity filters

Slow sand gravity filters often called slow sand filters are useful in the sense that they can remove much larger percentage of impurities and bacteria from the water, as compared to what can be removed by rapid sand gravity filters (often called rapid gravity filters). However, slow sand filters yield a very slow rate of filtration (about 1/30th of that given by rapid gravity filters) and require large areas, and are costly for large capacity schemes. For small capacity schemes of 3 MLD, slow sand filters are useful.

With the advancement of disinfection techniques, the necessity of too much purification and that of the maximum removal of bacteria (as is achieved by the slow sand filters) has decreased, and therefore, the slow sand filters are becoming obsolete these days. In the modern treatment plants, rapid gravity filters are almost universally adopted now-a-days. The water from the coagulation – sedimentation plant is directly fed into the rapid gravity filters, and the resultant supplies are disinfected for complete killing of germs and colour removal.

Theory of Filtration

The filters, in fact, purify the water under four different processes. These processes or actions are summarised below:

- Mechanical straining. The suspended particles present in water, and which are of bigger size than the size of the voids in the sand layers of the filter, cannot pass through these voids and get arrested in them. The resultant water will, therefore, be free from them. Most of the particles are removed in the upper sand layers. The arrested particles including the coagulated flocs form a mat on the top of the bed, which further helps in straining out the impurities.
- Flocculation and sedimentation:- It has been found that the filters are able to remove even particles of size smaller than the size of the voids present in the filter. This fact may be explained by assuming that the void spaces act like tiny coagulation-sedimentation tanks. The colloidal matter arrested in these voids is a gelatinous mass and, therefore, attract other finer particles. These finer particles thus settle down in the voids and get removed.
- Biological metabolism:- Certain micro-organisms and bacteria are generally present in the voids of the filters. They may either reside initially as coatings over sand grains, or they may be caught during the initial process of filtration. Nevertheless, these organisms require organic impurities (such as algae, plankton, etc.,) as their food for their survival. These organisms, therefore, utilise such organic impurities and convert them into harmless compounds by the process of biological metabolism. The harmless compounds so formed, generally form a layer on the top, which is called schmutzdecke or dirty skin. This layer further helps in absorbing and straining out the impurities.
- Electrolytic changes. The purifying action of filter can also be explained by the theory of ionisation. According to this theory, a filter helps in purifying the water by changing the chemical characteristics of water. This may be explained by the fact that the sand grains of the filter media and the impurities in water carry electrical charges of opposite nature. When these oppositely charged particles and the impurities come in contact with each other, they neutralise each other, thereby changing the character of the water and making it purer. After a certain interval, the electrical charges of sand grains get exhausted and have to be restored by cleaning the filter.

Filter Materials

Sand:- Sand either fine or coarse is generally used as filter media. The layers of sand may be supported on gravel, which permits the filtered water to move freely to the under-drains, and allows the wash water to move uniformly upward.

The filter sand should generally be obtained from rocks like quartzite, and should contain the following properties:

- It should be free from dirt and other impurities
- It should be uniform in nature and size
- It should be hard and resistant
- It should be such as not to lose more than 5% of its weight after being placed in hydrochloric acid for 24 hours.

The size of the sand is measured and expressed by the term called effective size. The effective size, i.e., D_{10} may be defined as the size of the sieve in mm through which ten per cent of the sample of sand by weight will pass. The selection of the correct effective size is very important, because too smaller size will lead to very frequent clogging of filters, and will give very low filtration rates. Similarly, too large size will permit the suspended particles and bacteria to pass through it, without being removed.

The uniformity in size or degree of variations in sizes of particles is measured and expressed by the term called uniformity coefficient.

The uniformity coefficient i.e., D_{60} / D_{10} may be defined as the ratio of the sieve size in mm through which 60 % of the sample of sand will pass, to the effective size of the sand.

Gravel: - The gravel which may be used below the sand should be hard, durable, free from impurities, properly rounded, and should have a density of about 1600 kg/m³.

Slow Sand filters

Scope and Limitation: Slow sand filtration is one of the most effective, simplest and least expensive water treatment processes. Although slow sand filters are capable of coping with turbidities of 50 mg/l or less for longer periods. In case higher turbidity is expected, some arrangements such as plain sedimentation for turbidities 20-100 mg/l, rapid roughing filtration for turbidities 20-50 mg/l and sedimentation followed by rapid roughing filtration for turbidities of 50-200 mg/l are required to be provided. Sectional schematic diagrams of Slow Sand Filters are shown in Fig. Nos. 7.10, 7.11, 7.12 & 7.13

Slow sand filters cannot be provided where land is either restricted or very expensive. In every cold climate when temperature drops below 6°C for any considerable period, precautions such as covering of filters becomes necessary for efficiency of purification process. The cost of providing slow sand filters with roofing requirement for large area is expensive. The covering of filters also becomes necessary to exclude water bearing algae content is essential; otherwise there will be problem of premature choking. It is an expensive addition to capital cost.

The oxygen content of filtered water should not fall below 3 mg/l otherwise anaerobic conditions will prevail. Under such conditions aeration of raw water to increase the oxygen content is called for.

Filter Design and Construction

- a) **Pretreatment:** Ordinarily pretreatment is not required for slow sand filters but slow sand filters normally do not run economically when raw water has turbidity over about 30 NTU for longer periods. Under such conditions, pretreatment by making plain sedimentation or roughing filtration arrangement permit economical filtration by bringing down the raw water turbidity below 30 NTU without entailing a complex process of coagulation.

Sometimes micro strainers are used in order to reduce excessive algae content particularly when source of water is an impounding reservoir. Occasionally a small dose of 0.15 ppm of

copper sulphate may be applied. Application of copper sulphate is more effective if pre-sedimentation is available.

As a precautionary measure, an application of chlorine to the effluent is necessary even where no other treatment except filtration is contemplated.

- b) Design Details : The CPHEEO manual suggests the design period for slow sand filters for 10 years because there is no economic advantage in building large plants to serve long years into future. A slow sand filter is a water tight basin made of RCC.
- i. Enclosure tank. It consists of an open water-tight rectangular tank, made of masonry or concrete. The bed slope is kept at about 1 in 100 towards the central drain. The depth of the tank may vary from 2.5 to 3.5m. The plan area of the tank may vary from 2000 sq.m or more, depending upon the quantity of water to be treated.
 - ii. Filter media. The filtering media consists of sand layers about 90 to 110 cm in depth, and placed over a gravel support. The effective size (D_{10}) of the sand varies from 0.2 to 0.4 mm. Sand layer of 15cm thick is generally of finer variety than that of the rest, which is generally kept uniform in grain size. However, if different gradations of sand are used then the coarsest layer should be placed near the bottom, and the finest towards the top. The finer the sand used, the purer will be the obtained water, as more impurities and bacteria will be removed.
 - iii. Base material. The base material is gravel, and it supports sand. It consists of 30 to 75 cm thick gravels of different sizes, placed in layers. Generally, three to four layers each of 15-20 cm depth are used. The coarsest gravel is used in the bottom most layer, and the finest gravel is used in the topmost layer. The size of gravel in the bottom-most layer is generally kept 40 to 65 mm; in the intermediate layers, as varying between 20 to 40mm, and 6 to 20mm (when two intermediate layers are used); and in the top-most layer as 3 to 6 mm.

Filter gravel should be so graded as to prevent the penetration of sand and yet provide for the free flow of water towards under drains. Cox recommends the following acceptable minimum depth of filter graded gravel:

Gravel Size	Depth of Gravel
Passing 80mm screen but held on 10 mm	15 cm
Passing 25 mm screen but held on 10 mm	5 cm
Passing 10 mm screen but held on 5 mm	5 mm

- iv. Under-drainage system: The gravel support is laid on the top of an under-drainage system. The under-drainage system consists of a central drain and lateral drains. The laterals are open jointed pipe drains or some other kind of porous drains placed 3 to 5 m apart on the bottom floor and sloping towards a main covered central drain. The laterals collect the filtered under and discharge it into the main drain, which leads the water to the filtered water well. Sometimes, instead of placing it in the centre, the main drain is placed along one side of the tank, and the laterals slope towards it.

-
- v. Number of Filter beds: Keeping in view the changes in raw water quality and uncertainties in operation and maintenance it is desirable to design slow sand filters for a normal filtration rate of 0.1 m/hr. A minimum of two filter units should be provided. This will restrict the overload rate to 0.2 m/hr when one unit is taken out for cleaning and would ensure uninterrupted supply. There is no need to provide for any standby unit. The number of filter units for a given area can be increased to gain higher flexibility and reliability. For a given area, the optimum number and size of filters which will be only 10% more expensive than the minimum 2 bed units are recommended.
 - vi. Future Extension: While designing the filters due consideration should be given to likely future extension so that necessary provision can be made in the original proposal. The size of pipes should be of sufficient capacity to cope with future requirement. Necessary arrangements should be made by providing suitable tees and blank ends.
 - vii. Inlet and Outlet arrangements. An inlet chamber is constructed for admitting the effluents from the plain sedimentation tank without disturbing the sand layers of the filter and to distribute it uniformly over the filter bed. A 'filtered water well' is also constructed on the outlet side in order to collect the filtered water coming out from the main under-drain. In order to maintain a constant discharge through the filter, an adjustable telescopic tube is generally used. Inlets and outlets are generally governed by automatic valves.
 - viii. Other appurtenances. Some other appurtenances are provided for the efficient functioning of these filters.

Vertical air pipe : It is a pipe passing through the layer of sand may be provided, and may help in proper functioning of the filtering layers. Similarly, arrangements are made in order to control the depth of water above the sand layer (1 to 1.5 m.). This depth is not allowed to undergo large variations.

Meter: It is used to measure the flow and a gauge is usually installed to measure the loss of head. The loss of head caused by the resistance offered by the sand grains to the flow of water through it is usually called filter head or filtering head. It is the difference of water levels between the filter tank and the filtered water well. For a freshly cleaned filter unit, the resistance offered is less, and, therefore, the filter head is usually small, say 10 to 15 cm, but goes on increasing as the filter layers get clogged, and telescopic tube is adjusted by manual labour, so as to maintain a uniform discharge. But when this loss of head becomes high (0.7 to 1.2m or so) the filter unit must be put out of service and be cleaned.

Weir : The weir plays an important role in the proper and efficient functioning of the filter. Weir serves many purposes:

- i. Prevents development of negative head in the bed leading to air binding (When sill of the outlet weir placed in level with the top of sand bed),
- ii. Aerates the effluent increasing its oxygen contents and releasing dissolved gases like carbon dioxide.,
- iii. Serves as measuring device when arrangements made by fixing 'V' notch or shape given to act as rectangular weir.

Good ventilation should be provided to weir structure to provide oxygenating air and to avoid accumulation of gas.

7.8. Design parameters for Slow Sand Filters

The design parameters as recommended in CPHEEO Manual are

- 1) Rate of Filtration : 100 lph /m² (Normal)
200 lph /m² (max.overload)
- 2) Design period : 10 years
- 3) No. of filter units :

Area in Sqm	No of units
Up to 20	2
20-249	3
250-649	4
650-1200	5

- 4) Depth of water over sand : 1m (exceptionally as high as 2 m)
- 5) Effective size of sand : 0.2 to 0.3 mm
- 6) Uniformity coefficient : 3.0 to 5.0
- 7) Sand (*Sand should not contain more than 2 % of calcium and manganese calculated as carbonate*)
- 8) Depth of sand bed : 1.0 m
- 9) Under drainage : General tendency of using standard bricks with dimensions 5 x 11 x 22 cm.
Joints in under drainage shall normally less in width
- 10) Gravel bed gradation : Top most layer 1 to 2 mm
(Normal depth of each layer Second layer 3 to 6 mm
Of 6 cm, the total depth 30 cm) Third layer 9 to 18 mm
Bottom layer 27 to 54 mm
- 11) Internal depth of filter bed : Free board. : 0.20 m
(Usual dimensions) Water depth : 1.00 m
Filter media : 1.00 m
Gravel drains : 0.30 m
Brick drains : 0.20 m
Total depth : 2.70 m
- 12) Effluent weir level above Sand bed : 20-30 mm
- 13) Length of filter run : Not exceeding 6-8 weeks

Operation and cleaning of slow sand filters

The treated water from the sedimentation tank is allowed to enter the inlet chamber and get distributed uniformly over the filter bed. The water percolates through the filter media and gets purified during the process of filtration. The water now enters the gravel layers and comes out as the filtered water. It gets collected in the laterals through the open joints, which is finally discharge into the 'filtered water well', from where it can be taken to the storage tanks for supplies. The rate of discharge or the rate of filtration is kept constant by arrangements like that of a telescopic tube.

It may also be noted that the water entering the slow sand filter should not be treated with coagulants. This is due to the fact that the dirty skin formed by the floc and carried to the filter considerably affects the economical working of the filter.

The depth of water on the filter should also be decided carefully and should not be allowed to undergo large variations. This depth should neither be too large nor it should be too small. It is generally kept equal to the depth of the filter sand.

The loss of head called filter head or filtering head or filtration head is generally limited to a maximum value about 0.7 to 1.2m. When this limiting value, which is roughly kept as 0.7 to 0.8 times the depth of the filter sand, is reached, the filter unit must be put out of service and the filter shall be cleaned.

After each cleaning, the filter is again used and raw water is admitted into it. But the effluents that will be obtained in the beginning will not be pure and are not used for about 24 to 36 hours until formation of a film of arrested impurities around the sand grains (i.e., the formation of schmutzdecke) has taken place. Since the filtering action of slow sand filters depends largely upon the formation of this film, the effluents obtained in the beginning, when such a film is absent, shall not be pure.

The interval between the two successive cleanings depends mainly on the nature of impurities present in water and also on the size of the filtering sand used in the filter. This interval however, normally ranges between one to three months.

Rate of filtration for slow sand filters

The rate of filtration that can be obtained from the normal slow sand filters is less and usually ranges between 100 and 200 litres per hour per Sqm of filter area. The slow sand filters are recommended for rural water system since they are easy to operate and maintain, they required large area which however is usually available in a village. In case dissolved oxygen content of raw water falls below potential oxygen demand, anaerobic conditions will develop within the sand bed of the filter and it would necessitate increasing the oxygen content by aeration of inflow water. Aeration after the filtration is too late to prevent anaerobic conditions developing within the filter bed. In order to ensure that anaerobic conditions do not develop in the sand bed of filter, the oxygen content of the effluent should not be allowed to fall below 3 mg/l.

Initial commissioning of filters

In new filters vital living organism are not present in sand frame work on which the treatment depends. Creation of biological content in the filters is very slow process. Ripening of new filter may generally take about three weeks whereas a filter which has been cleaned in a single day operation may take only one to two days. The activity of microorganism lessens considerably as the temperature decreases or as the oxygen concentration of water in the filter medium falls below 0.5 mg/l. the process can be hastened in the original ripening State newly commissioned filter with some active material removed from some existing filter otherwise the following method of commissioning has to be resorted to.

All the outlets sluice valves of filters are closed and treated water introduced in the filter through the bottom so that the bubbles are expelled from the sand bed. Water is allowed to rise through the bed until the top of sand is covered by adequate depth of water say 80 mm to avoid disturbance of sand bed by turbulence from entry of raw water from top. A concrete slab may be placed on the surface of sand bed below the inlet to avoid disturbance caused by falling water. When water reaches normal working level in the tank, the outlet valve is opened and effluent is allowed to water at about one-fourth of the normal filtration rate. The filter will run for weeks or to another filter for several weeks depending upon the quality of raw water. For clear water more period is required for ripening process.

Filter Cleaning

Through slow sand filters water is passed through the layer of sand at the rate of about 100 to 150 lph/m² until the difference between the water levels in the filters and the outlet chamber or the loss of

head reaches 60 cm. it is not economical to run filters with loss of head more than 1.3 m or depth of water over the sand.

Cleaning operation is carried out very carefully by scrapping 2-3 cm of sand from the top of the filter by hand or mechanical equipment although the exact amount will depend upon the depth to which the silt has penetrated. This can be determined by the color of the sand, which is usually stained by silt. Minimum depth of 45 cm of sand is always maintained in the filter bed. Generally the period between cleaning operation with turbidities of about 30 NTU is six weeks. The sand scraped from the filter bed is cleaned in wash boxes and reused. Washing of sand is continued until about 40 % sand is removed.

For cleaning operation, inlet sluice valve is closed allowing the filtered water to clear water storage as long as water level reaches the weir level. Generally it takes over night. The delivery of clear water is then closed and the balance water in the filter is allowed to exhaust through scour valve. Unless a stand-by filtration capacity is available, the remaining filters will have to be over loaded by an increased filtration rate which understandably results in rapid clogging. For this reason it is advantageous to construct more number of small filters to avoid overloading.

Before the filter bed is refilled, the inside walls of filters should be cleaned to prevent algae and slime growth. Water is refilled by charging treated water from below either from clear water storage tank or from some other filter. When water depth over the sand bed reaches some 80 to 100 mm, raw water is gradually introduce. The regulating valve on the outlet line is closed substantially to compensate for less resistance due to cleaned filter bed.

Re-sanding

Twenty or Thirty scrapings in a period of several years will reduce the dept of sand to its minimum required level of 40 cm above the supporting gravel. It is preferable to remove this portion of sand bed before re-sanding operation to avoid enhanced resistance of this portion and fouling etc. Although it is economical to wash the scraped sand immediately and return it to the filter bed, saving transport and labour etc but this practice is discouraged because only top 0.05-0.10 m filter bed is washed and sand below this layer remains in place for abnormally long period resulting in persistent clogging.

Flow control

Constant water level in slow sand filters is maintained by means of float control valve. The effluent through filter bed is regulated through delivery wall and with help of effluent measuring device as already discuss.

Results of Slow Sand Filtration

The improvement of water quality brought about by slow sand filtration will differ from place to place because the process depends on many factors such as raw water quality, grain size, the rate of filtration, temperature and oxygen content of the water. An indication of purification effect often matured filter that is filter with a fully developed filter skin is summarized in table 7.2.

7.9. Performance of Slow Sand Filters

TABLE 7.2

Parameters of Water Quality	Purification Effect of Slow Sand Filtration
Colour	30 to 100% reduction
Turbidity	Turbidity is generally reduced to less than 1 NTU
Faecal Coliform	Between 95 to 100 % and often 99 to 100 % reduction in the level of faecal Coliform.
Cercariae	Virtual removal of Cercariae of schintosoma, cysts, and ova
Viruses	Virtually complete removal
Organic matter	60-75% reduction in COD
Iron and Manganese	Largely removed
Heavy metals	30-95% reduction
Filter runs	With raw material turbidity not exceeding 30 NTU, filter run should not be less than 6-8 weeks with filter head not exceeding 0.6 m

7.10. Horizontal Roughing Filters

Slow sand filters (SSF) find global application specifically in small community water supply scheme due to its added advantages of most qualitative, cost effective, simplest and reliable technology which requires limited professional scale and easy maintenance. SSF requires a few technical components, no chemicals and its performance is not controlled by mechanical system but by eco systems of living organisms.

However their narrow and stringent requirement of low turbidity limits (10-20 NTU) which is a major draw back for the influent water make it immediately susceptible to heavy, recurrent silting and choking especially during the rainy season due to heavy turbidity. This has resulted mostly in mal/non-functioning of such SSF. The practical experience with SSF reveals that most of SSF are facing operational problems or are even out of operation due to highly turbidity owing to major changes in surface water quality. Hence horizontal roughing filter (HRF) is an appropriate pretreatment technology for slow and filters (SSF) in case of raw waters having highly turbidity levels.

In HRF water runs in horizontal direction under gravity into a first chamber through a distribution box which maintains a reasonably uniform input across the width of the filters. From this chamber water flows horizontally via permeable barriers through three compartments in succession which contains coarse, medium and fine granular material. The flow being horizontal, thereby permitting it to archive a considerably greater filter length than would be with vertical flow filters such as SSF. HRF consists of differently sized relatively coarse filter material (ranging from 20 mm to 4 mm) which successively decreases in size to treat highly turbid water (300 to 400 NTU or even 1000 NTU for shorter duration) Sedimentation is the main solid separation process. Bacteriological water quality improvement is also observed to great extent. The resulting water quality from HRF is suitable for charging SSF since HRF reduces turbidity level down to about 20 NTU. SSF performance is improved in increasing the rate of filtration without affecting the water quality.

In HRF rate of filtration ranges between 0.3 and 1.5 m³/m²/h. length of filter (typical 10 m) is dependent upon raw water turbidity.

7.11. Rapid Gravity Filters

Filters design to operate at much higher rate than slow sand filters are called 'Rapid' Gravity Filters or Rapid Sand Filters. Schematic diagrams of Rapid sand filters are shown in fig.7.14, 7.15, 7.16 & 7.17

In this type of filters, the raw water first undergoes a preparatory treatment. Water entering the rapid sand filters contains flocks formed during the pretreatment process. The filter media used in this type of filter is of coarser variety and the operation head is also higher. A suitable pretreatment of raw water is of paramount importance for efficient performance of rapid gravity filters. Understandably no rapid gravity filter, which receives water without pretreatment of water with un-coagulated colloidal matter, can work satisfactorily. This filter remove large amount of impurities in a short time resulting in quick clogging necessitating, frequent washing with cleaning interval between 24 to 48 hours, depending upon the quality of water being fed to the filters. Since these filters require frequent cleaning no chance is left for formation of biological slime to form the filtering mat, as is in case of slow sand filters, which proves so much effective in improving the quality of the filtrate.

Rate of filtration

The standard rate of filtration recommended in CPHEEO manual on water supply and treatment is 80 to 100 lpm/m² (4.8 to 6 m³/m²/hr). In recent past, there has been a decided trend towards higher rates of filtration by using coarser sand and improving the pretreatment system. In the country a higher filtration rate of 240 lpm/m² is achieved. Usual practice is to adopt filtration rate of 80 lpm/m². Piping arrangements consisting of inlet and outlet etc. are designed at 100% over load for emergent situations.

Design of Filter Unit

- a) Area: Rapid sand filters should be so designed that the number of units should be sufficient for total quantity of water to be handled without any over loading. In the design of large size filter, very vital factor which deserves consideration is the rate of supply of wash water and the hydraulic problems in achieving equal distribution of wash water, area being large. CPHEEO Manual on water supply, Govt. of the India recommends the maximum area of 100 m² for single unit for plants greater than 100 MLD consisting of two halves each of 50 m² area. In order to obtain flexibility of operation, minimum of four units are recommended which should be reduce to two in case of small plants.

- b) No. of Units: Morrell and Wallace developed an equation which may be used as a guide for number of filter units. It is $N = Q / 4.69$, where

N = Number of filter units

Q = Plant capacity in M³/ hour

Allowing for repairs, renewals etc., the bed could be designed for 23 hours of operation per day or alternatively extra bed may be provided to make up for this loss of time.

- c) Dimensions : As for the dimension of the filter box, the ratio of length to width averages 1.25 to 1.33 and minimum over all depth of 2.6 m including a free board of 0.5 m is adopted. The settled water is brought into filters in such a manner that it causes least turbulence; otherwise it will break up the residual flocs. The filter boxes are constructed in R.C.C or masonry (stone or brick). The CPHEEO manual recommends that where seasonal extreme temperature or not prevalent, it is not necessary to provide roofing over the filters, the operating gallery alone being roofed over.

- d) Specification of sand: Since sand bed is the heart of filtration plant, selection of sand needs great care. Although finer sand is more effective in filtration of water, it has higher frictional resistance and as such it cannot be economically used except in case of slow sand filters.

The sand should be of following specifications

- i. Effective size of sand shall be 0.45 to 0.70 mm.
 - ii. Uniformity coefficient shall be 1.3 to 1.7.
 - iii. Sand shall be hard, resistant quartz and free from clay, dust, roots and other impurities.
 - iv. It should contain less than 2 % lime and magnesium calculated as carbonates and soluble in dilute hydrochloric acid in 24 hours at a temperature of 70°F.
 - v. Silica contents should not be less than 90%
 - vi. Specific gravity shall be in the range of 2.55 to 2.65
 - vii. Wearing loss shall not be more than 3 %
 - viii. Ignition loss should not exceed 0.7 % by weight.
 - ix. Soluble fraction in hydrochloric acid shall not exceed 5 % by weight
- e) Depth of sand: The layer of sand is usually 60-75 cm. The depth of water over this sand top varies between 1 m to 2 m. The free board shall be at least 50 cm.

The depth of sand that can be checked against break through of floc through sand bed depth required by Hudson formula:

$$Qd^3h/l = B \times 29323 \text{ where}$$

Q is in $M^3/M^2/h$, d in mm sand size and h and l in m, terminal head loss and depth of bed respectively.

B is break through index whose value ranges between 4×10^{-4} to 6×10^{-3} depending upon response of coagulation and degree of pretreatment in filter influent. Assume $B = 4 \times 10^{-4}$ for poor response to filtration and average degree of pretreatment, terminal head loss of 2.5 m, rate of filtration = $5.0 \times 2 = 10 \text{ m}^3/\text{m}^2/\text{hr}$ (assuming 100% over loading of filters under emergencies) and assuming d = 0.6 mm as mean diameter.

$$10 \times (0.6)^3 \times 2.5 = 4 \times 10^{-4} \times 29323$$

Minimum depth of sand required to avoid break through = 46 cm. Hence assumed depth of 60 cm is adequate to avoid break through of flocs.

- f) The Gravel Layer: The function of gravel layer is to support sand layer and to distribute wash water. The gravel should preferably be natural rounded and not crush stone. The specification of gravel, as recommended by Cox in WHO monograph series 49, 'operation and Control of water Treatment Processes' as shown in table 7.3.

TABLE 7.3

Range in size, mm	Range in depth, cm
63-38	13-20
38-20	8-13
20-22	8-13
12-5	5-8
5-2	5-8
Total Depth	39-62

CPHEEO Manual on water supply and Treatment recommends the size of gravel from 50 mm at the bottom to 2 to 5 mm at the top with 45 cm depth.

The gravel and its size gradation can be estimated as under:

Assume a size gradation of 2 mm at top to 50 mm at the bottom. The requisite depth l in cm of component gravel layer of size d in mm can be computed from empirical formula.

$$l = 2.54 k (\log d)$$

K varies from 10 to 14

for $K=12$, the depth of various layer of gravel are:

Size, mm	2	5	10	20	40
Depth, cm	9.2	21.3	30.5	40	49
Increment, cm	9.2	12.1	9.2	9.5	9

Provide a gravel depth of 50 cm

For strainer or wheeler type under-drain system, minimum size of gravel shall be 2 mm and maximum 50 mm with 30 to 50 cm depth and for perforated pipe under drain system, size of gravel shall be 2 mm minimum and 25 mm maximum with 50 cm depth

- g) Filter Bottom and Under Drainage System: The function of the under drainage system is to collect the filter water reaching down through the sand and gravel layer and to distribute uniformly upward the back wash under-neath the gravel.

Because the rate of wash water is several times higher than the rate of filtration, the rate of wash water is therefore the basis of design for under drainage system. Various types of under drainage system are adopted. Most commonly used under-drainage systems consist of grid of pipes into which strainers are fitted. A.C.I main, called 'Manifold' is placed longitudinally along the centre of the bottom floor which several 75-100 mm dia pipes called 'Laterals' placed across spaced 150 to 200 mm centre to centre. Another system consists of vitrified clay blocks with perforations at intervals. Still another type of system is of porous silica plates mounted on the support. The system has the draw back of getting clogged by minute quantities of alumina.

The pipe grid system consists of cast iron, asbestos cement or concrete pipe etc. the design criteria for manifold and laterals, warrants that the loss of head occurs in the strainers or openings and not in the manifold or laterals in order to achieve uniform flow of wash water and rate of filtration through out the area of filter. The velocity of jets issuing from openings or strainers is lost against the filter bottom or in the layer of supporting gravel surrounding the pipes.

The head lost should, therefore, be equal to the driving head during wash. Usually the controlling head is set between 1 to 4.5m. The ratio of total area of opening in the under drains to total cross sectional area of laterals should not exceed 0.5 for perforations of 12 mm size and should reduce to 0.25 for perforation of 5 mm. The ratio of total area (perforations) to the filter area should preferably be 0.003 to 1 except with special bottoms. A filter area of 100 m² would be provided with under-drain perforations having total area of 0.3 m². The total cross sectional area of laterals should be about twice the total area of strainers or laterals opening and cross sectional area of manifold should be equal to 1.5 to 2 times the total that of laterals. The ratio of length to dia of laterals should not exceed 60.

The spacing of laterals is approximately equal to spacing of orifices and shall be equal to 30 cm. In general filtered water and wash water piping should be designed to provide a velocity of flow not greater than 0.9-1.8 m/sec and 2.4-3.6 m/sec respectively

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- h) Wash Water Troughs: Wash water troughs are constructed in concrete, asbestos cement, plastic and steel etc. Wash water troughs are located in such a manner that the horizontal travel of dirty water over the surface of sand in the filter box is kept between 0.6 to 1.0 m before it reaches the trough, but there are successful units where dirty water travel has been as high as 3 m, as recommended by CPHEEO manual. For free falling rectangular trough with level invert, the discharge capacity Q in m^3/sec may be computed from the equation $Q = 1.376 bh^{3/2}$, where b is the width of trough in m and h is water depth in m.

Wash water troughs should be so located that their lower surface is slightly above the expanded sand i.e. 50 mm or more during filter washing with cross sectional area sufficient to provide required capacity. The top edge of the trough should be as far above the undisturbed sand surface as the wash water rises in one minute. Necessary adjustment can be made by selecting a size with more width and less depth. The trough should be large enough to carry all the water delivered to it with atleast 50 mm space between the surface of flowing water in the trough and the upper edge of the trough. Any submergence of trough will reduce the efficiency of wash.

- i) Washing of a filter: Washing of a filter is done with clean water which can be managed from either pumping clear water from clear water gallery to wash water tank or from distribution mains, if the distribution line is available nearby treatments units or from the rising main if the treatment units are located near the pumping main, as the case may be.

The necessity of washing a filter arises when the filter media gets so dirty that maximum gravity head is required to force the water through filter bed. The material deposited on sand through the course of filtration process, increases the resistance to the flow of water. When the loss of head becomes too great, filter is washed. For this purpose loss of head indicators are provided to show the condition of the filter sand. Filter should be washed when loss of head reaches 1.8 to 2 m. In clear filter initial loss of head is 0.10 to 0.15 m. Length of filter run should not be less than 24 hours with a loss of head not more than 2.0 m.

- a) Process of washing: Washing of filter is not merely an operation of a flow control valve; rather it deserves more attention to make the back washing process really effective.

For achieving the best result the following steps should be adopted.

1. Close the influent valve A and allow the water level on the top of sand to drop till it reaches a point just 15 cm above the sand this way the settled water is conserved.
2. Close the delivery sluice valve D.
3. Conduct inspection of filter beds to check cracks, mud balls and mounds etc.
4. Open the scour valve B.
5. Gradually open the wash water sluice valve C taking 50 to 60 seconds time to apply a flow at the rate of above $0.5 \text{ m}^3/\text{m}^2/\text{min}$, failing which wash water will be introduced so rapidly that compacted surface of sand is uplifted as a mass until a portion cracks and clean bottom sand and small size gravel is carried towards crack in fast horizontal flow.

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6. Continue washing at low rate for 2-3 minutes to afford sufficient time for the floc to get dislocated. Wash water rising through laterals, strainers, gravel and sand carrying with it arrested impurities will be collected by the troughs and passed out through the scour valve.
 7. Open wash water sluice valve 'C' further so as to give maximum sand expansion decide such as 40 to 50 % and it should be continued for a period of one minute or till water becomes relatively clearer. Now closed the wash water sluice valve and also close the scour sluice valve. Valve E which allows filtered water to waste to sewer is then opened. Allow the sand to settle for 2 minutes and then close the valve.
 8. Open gradually influent sluice valve A ensuring some water cushion is available on the top of sand to avoid unnecessary turbulence and open more sluice valve to make the water reach its normal level and then open the outlet sluice valve to put the filter bed back to use.

- b) High Velocity Wash Water System: High velocity wash water is applied normally where no other agitation (air agitation) is provided. The rate at which the wash water is applied is 600 lpm/m² of filter surface or 60-70 cm/min rise in the filter box for the period of 10 minutes. The sand should expand 130 to 150 % of its undisturbed volume. For high rate wash, the pressure in the under drainage system should be 6-8 m with wash requirement being 700 l/m/m² for a duration of 6 to 10 minutes. If the pretreatment is effective, the quantum of wash water would amount to 1% to 2.5% of the total amount of water filtered each day. Amount in excess of 2.5 % indicates the need to investigate for corrective action.

Cox in 'operation and control of water treatment processes (WHO monograph series 49) recommends the modern practice to design wash water system to produce rate upto 56 m³/m²/h or 90 cm raise/min. (Allowance for high water temperature in tropics justified the use of maximum rate upto 72 m³/m²/h or 120 cm rise/min). Rate of rise of wash water depends upon the Effective Size and Uniform Coefficient of sand used.

Capacity of back wash pumps and wash water tank: Pumps required filling up the wash water in less than 8 hours are provided. The tank should be of sufficient capacity (normally to hold 1.5 times the volume of water needed to wash a single bed) to back wash one filter for atleast 10 minutes at the designed rate of wash water flow. Where numbers of filter units are four or more, the capacity of the storage tank must be sufficient to supply wash water to two filter units, at a time. The height of wash water tank should be sufficient to provide the desire rate of flow.

- c) Surface wash system: There is a recent development to supplement conventional back washing by means of surface wash. In this system the stirring of expanded filter bed is done mechanically with rakes and hydraulically with jets of water. The grid of the pipe for using the surface wash consists of horizontal header pipes suspended on wash water trough. Secondary pipes vertically down wards are connected with horizontal headers, extending within 10 cm of the surface of sand bed. The bottom tips of the vertical pipes of not less than 25 mm dia have holes of 2.5 mm dia at an angle of 30° to the horizontal. The spacing of vertical pipes is maintained at 60-75 cm, centre to centre. The pressure used in the system

ranges between 0.70 to 2.10 kg/cm². The system can be installed in the existing filter beds also. The rotatory type shall consist of rotating unit suspended at a height of 50-75 mm at adequate intervals to provide complete coverage. Jet nozzles are on sides and bottom to rotate at a rate of 7 to 10 rpm.

- d) Air Wash System: In this system, compressed air is used to achieve scrubbing action with less volume of water. Compressed air is forced through the under drain system before wash water. It is preferable to use air through separate piping located in between gravel and sand. It results in better washing. In separate air piping, air is introduced in about the same volume and at the same time water is introduced through the under drains. Air is forced at the rate of 0.6 to 0.9 m³ of free air per minute per square meter of filter area @ 0.35 kg/cm² till such time the bed is thoroughly agitated i.e. for about 5 minutes, and water is forced through separate under drain system simultaneously at the rate of 0.4 to 0.6 m³/m²/minute.

In common system of under-drainage piping for air and back wash, the volume of air and back wash being the same, free air is forced through the under-drains until the sand is thoroughly agitated i.e. for about 5 minutes. Wash water is then introduced through the same under-drains at the rate Stated in the former case.

There is trend to discourage air wash system because poor results are achieved with limited volume of wash water. This difficulty can be over come by increasing the capacity of wash water pump to feed sufficient quantity of water to remove dirt from the loosened material.

7.12. Design Parameters of Rapid Sand Filters

The design parameters given below are based on the recommendations given in CPHEEO Manual as shown in the table 7.4.

TABLE 7.4

1	Rate of filtration	80 lpm/m ² with inlet and outlet designed for 100% over load
2	No. of filter units	Morrel and Wallace formula Where $N = \sqrt{Q / 4.69}$ No. of filter units $Q = \text{Plant capacity m}^3/\text{h}$ Minimum= 2 No.s
3	Area	Max. 100 Sqm for single unit, for plants greater than 100 MLD, consisting of two halves. Each 50 Sqm. Min 4 units reduced to 2 in case of small plants.
4	Dimensions	Length to breadth ratio =1.25 to 1.33
5	Depth of filter box	Overall 2.6m. Including 0.5m free board.
6	Design criteria for sand	Effective size 0.45 to 0.70 mm. uniformity coefficient not more than 1.7 or less than 1.3
7	Depth of Sand	Average depth 0.75m.
8	Design criteria for gravel	As per gravel layer design given above
9	Under drainage system, thumb rule	As recommended by Cox. For filters washed at the rate of 15 cm to 90 cm/min wash water rate of rise a) Ratio of total area of orifices to the filter area served in the range of 0.15 to 0.5% and preferably about 0.3%. b) Ratio of cross sectional area of lateral to area of orifices served 2 to 4:1 preferably 2:1. c) Dia of orifices: 6mm to 18mm. d) Spacing of orifices: 30 cm for 18mm dia orifice, and 7.5 cm for

		6mm dia. e) Ratio of areas of manifold feeding the laterals to the area of laterals served 1.5 to 2:1. f) Spacing of lateral: closely, approximately spacing of orifices. g) Length of lateral on each side of manifold: not more than 60 times their dia. h) Orifices located downward from 30° to 60° with vertical.
10	Filter back washes (with water alone)	Hydraulics of system to be fixed on 50% sand expansion. Modern practice to design wash water rate of rise 90 cm/min. in the filter box. In tropical weather, with high temperature, max. rates upto 120 cm/min. are justified. Erosion or corrosion of metal around these holes may be minimized by lining the holes with a brass or bronze bushing.
11	Back wash with air water	Compressed air used @ 0.6 to 0.9 m ³ /m ² /min of filter surface @ 0.35 kg/cm ² pressure for 5 minutes. Then wash water @ 0.4 to 0.6 m ³ /m ² /min.
12	Wash Air tank	Capacity to hold at least doubles the amount of air necessary to wash one filter. Capacity of compressor to refill the tank between washings.
13	Surface wash system	In addition to conventional wash system, through separate pipe grid under pressure 0.7 to 2.10 kg/cm ² .
14	Filter bed agitators	Wash water under at least pressure of 2.7 atm. The jet action causes arm to revolve 18 rpm
15	Mechanical rakes	Speed @ 10-12 rpm
16	Wash water troughs	Spacing, so that each trough serves same filter area. Max. Horizontal travel of dirty water is kept between 0.6m to 1.0m. Thus the distance of trough from the wall shall not be more than 1.0m and clear distance between two troughs to be not more than 2.00 m. Lower surface of trough above the sand surface to permit 50% expansion without having sand grains hit the troughs. Bottom of trough may be horizontal or in slope not exceeding 1 in 37. Top of trough to be always horizontal. Formula: $Q = 1.376 bh^{3/2}$ where b=width of trough in m. h=water depth in m. Q=flow in m ³ /sec
17	Gullet	Slightly larger than double the x-section of trough
18	Wash water tank	Capacity of wash water tank 1 to 6% of filtered water. Sufficient for at least 10 minutes wash of one filter at design rate or 5 to 6 minutes wash of two filters without refilling or 1.5 times the volume of water required for single bed for at least 10 minutes. Bottom of tank normally 9 m to 11 m above wash water troughs.
19	Pressure as measured in under drains	4.5 m or 5.0 m
20	Means of wash.	i. Elevated tank into which water is pumped at a rate to fill the tank between washings. ii. Wash water pump which operates only when filter is being washed. iii. By taking water from distribution system.
21	Pumping equipment	In duplicate, as a factor of safety capable of filling up the wash water tank in less than 8 hours.

22	Depth of water over sand	1.0 to 2.0m
23	Free board	0.5m
24	Head loss	2.5m (min) to 3.0 m (Max)
25	Conduit Dimensions	velocity, mps i. Influent conduits carrying raw water. ---- 0.9 to 1.8 ii. Influent conduits carrying flocculated water. ---- 0.8 to 1.8 iii. Influent conduits carrying filtered water. ---- 0.9 to 1.8 iv. Drainage conduit carrying spent wash water: ---- 1.2 to 1.4 v. Wash water conduit carrying clear wash water:--- 2.4 to 3.6 vi. Filter to waste connection : --- 3.6 to 4.5
<i>(Inlet and outlet designed to permit 100% overload for emergent situations)</i>		

7.13. Comparison of filters

- **Rate of Filtration** : The major difference in various types of filters lies in the filtration head *i.e.* the head which makes water to flow through the filter and consequently the rate of filtration. The rate of filtration in slow sand filters is about 2 to 2.5 lpm / m² whereas the rate of filtration through rapid sand filters is usually 80 to 100 lpm/m². Thus the rate of filtration through rapid type is 40 to 50 times faster than those of the slow type.
- **Area Requirement**: Keeping in view the rate of filtration, the area required for rapid sand filters is theoretically only 4 to 5% of the area needed for slow sand filters. In practice, the reduction in the area requirement is partly off set by the additional space needed for pretreatment works required with rapid type filtration and the figure is thus likely to be around 20 %. Slow sand filters require large area, correspondingly large structure and volume of sand.
- **Loss of Head** : The head loss in slow sand filters ranges between 1.0m to 1.5 m, while it is 2.50 m to 3.0 m in case of rapid sand filters.
- **Compactness of Design**: As already discussed slow sand filters need large areas for their installation but are simple to operate where as rapid filters can be constructed in more compact units fitted with automatic devices. Water in case of slow sand filters is exposed to sun shine and thus algae growth is encouraged.
- **Filter Media**: Filter media required in slow sand filters consists of finer sand while sand used in rapid type filters is of coarser quality.
- **Flexibility in Operation**: In rapid types filters adjustments can be made according to variation in demand where as slow sand filters are less flexible to meet any emergent situation of demand.
- **Method of Cleaning Filters**: Slow sand filters require infrequent operation of cleaning by unskilled laborers using hand tools not requiring regular flushing to waste of wash water. Unless the water being treated is of high turbidity, slow sand filter may work for weeks together even months without involving cleaning operation. The necessity for cleaning rapid type filter arises at frequent intervals usually only after one or two days. Cleaning is generally done by high pressure back washing and compressed air or mechanical agitation is used. The system is more sophisticated requiring constant and skilled supervision. Wastage of water required for back washing is 2 to 3 % of total water treated.
- **Pre-treatment** : Rapid filters cannot run without pretreatment such as coagulation and flocculation etc which are expensive processes while slow filters do not need pre-

treatment of water, but slow sand filters work well only when the turbidity does not exceed 50 ppm.

- Post Filter Treatment: The filtrate from rapid sand filters need disinfection where as water from slow sand filters can be supplied without any further treatment.
- Bacterial purification: Slow sand filters give effective bacterial removal. The pathogenic bacteria are completely eliminated to 99 % in slow sand process where as only fixed bacterial load is removed in rapid sand filtration process thus necessitating post chlorination.
- Color and Odour: Slow sand filters are less effective in removing color and odour from water. These give poor results with water of high algae content unless pretreatment is practiced while rapid sand filters can effectively handle color and odour problem.
- Corrosiveness: Addition of coagulants increases the acidity and reduces pH value rendering the water corrosive. Slow and filters do not need addition of chemicals and thus produce an effluent, which is more uniform in quality and is less corrosive.
- Pressure filters: Pressure filter consists of closed vessel usually of steel containing a filter media through which water is forced under pressure. In this process water under pressure is subjected to filtration without the pressure being dissipated and thus it avoids double pumping. The pressure filter cylinders are designed to send water pressure of 10kg/cm². Although as per practice, rate of filtration usually is weakness of these filters, due precaution is needed even at 4.8 m³/m²/h as rate of filtration.

7.14. Disinfection of water

The process of killing the infective bacteria from the water and making it safe to the user is called disinfection. It does not mean total destruction of all living things in the medium treated, because sterilization means total destruction. The filters are unable to remove all the disease bacteria. They can remove only few types of bacteria. Therefore the water which comes out from the filter may contain some disease-causing bacteria in addition to the useful bacteria. Before the water is supplied to the public it is utmost necessary to kill the disease causing bacteria. The presence of color, minerals, turbidity etc is not dangerous to the public as the presence of disease causing-bacteria, because they may lead to the spread of various diseases and their epidemics causing disasters to the public life.

Methods of disinfection

The disinfection of water can be done by the following common methods:

- By boiling water
- By passing ultra-violet rays
- By use of iodine and bromine
- By use of ozone
- By use of excess lime
- By using potassium permanganate
- By treatment with silver or electro-katadyn process.

Disinfection by boiling; The water can be disinfected by boiling for 15 to 20 minutes. By boiling water all the disease-causing bacteria are killed and the water becomes safe for use. This process can only kill the existing germs but does not provide any protection against future possible contamination.

Disinfection by Ultra-violet Rays: Ultra-violet rays are invisible light rays having wave lengths of 1000 to 4000 m. Sun rays also have ultra-violet rays which can also be utilized in the disinfection of water. In the laboratory they can be obtained by the ultra-violet ray equipment, which essentially consists of mercury vapours enclosed in quartz bulb and passing current in it. Ultra-violet rays are highly disinfects and kills the disease bacteria. After removing the turbidity and the color of water, then disinfection by ultra-violet rays can be done.

Disinfection with iodine and bromine: It has been seen that addition of Iodine and Bromine in the water kills all the pathogenic bacteria. The quantity of Iodine and Bromine should not exceed 8 ppm and they can kill bacteria in minimum contact period of 5 minutes.

Disinfection with ozone: Ozone is an excellent disinfectant. It is used in gaseous form, which is faintly blue in color of pungent odour. Ozone is an unstable allotropic form of oxygen, with its every molecule containing three ozone atoms. But as the ozone is highly unstable, it breaks down in the ordinary oxygen and liberates nascent oxygen.

Disinfection by excess lime: Lime is usually used at the water works for reducing the hardness of water. It has been noted practically that if some additional quantity of lime is added than what is actually required for removal of hardness, it will also disinfect the water while removing the hardness.

Disinfection by Potassium Permanganate: This is the most common disinfectant used in the village for disinfection of dug well water, pond water or private source of water. In addition to the killing of bacteria it also reduces the organic matters by oxidizing them. Due to its good oxidizing quality, it is sometimes added in small dose 0.05 to 0.10 mg/litre in the chlorinated water. In the rural areas it is common practice to dissolve a small amount of potassium permanganate in a bucket of water and mix it with the well water frequently, to kill the bacteria.

Disinfection with Silver of Electro-Katadyn Process: This is very costly method of disinfection, hence not used at the water works. In this method the metallic silver ions are introduced into the water by passing it through solid silver electrodes tubes and passing the current through 5 V D.C. battery.

Disinfection with chlorine

Chlorination with Chlorine gas using a vacuum chlorinator is a very effective disinfection process for water treatment. It is cheap, easily available, reliable, and easy to handle, easy to measure and it is capable of providing residual disinfecting for a long time, thus protecting from future contamination. The schematic diagram of chlorinator with injector is shown in Fig.7.18 & 7.19.

Forms of chlorine

- Free chlorine in the form of liquid chlorine or as chlorine gas
- As combined chlorine in the form of bleaching powder.

The bleaching powder contains 30 to 35 % of chlorine when it is fresh. Since bleaching powder loses its chlorine content with time, it is desirable to assume that bleaching powder contains 25 % of chlorine while determining dosage of bleaching powder. Hence, in order to give a chlorine dosage of 1 mg / lt. Bleaching powder of 4 mg/lt is to be dosed. After addition of the bleaching powder the residual chlorine in the OHSR water has to be about 1 mg/lt, to ensure minimum residual chlorine of 0.2 to 0.3 mg/lt at the consumption point. Any abnormal changes in the residual chlorine level or absence of residual chlorine will indicate the contamination of water.

A chloroscope shall be used to check the residual chlorine content. A sample of water is taken in a test tube and a few drops of the reagent is added to the water and shaken. If residual chlorine is present,

the water in the test tube will turn to yellow. The concentration of residual chlorine is indicated by the intensity of the yellow colour i.e., the deeper the yellow, higher will be the concentration of residual chlorine. The comparator kit provides accurate comparison of colours and hence assesses quantity of residual chlorine.

Chlorinators are used for liquid/gas chlorine. Differential pressure type chlorinator can be used for dosing of chlorine through online chlorination. A schematic diagram of differential pressure type chlorinator is shown in Fig 7.3. In this case, the differential pressure chlorinator is fitted into the raising main. Here bleaching powder solution is introduced into pumping mains using the principle of differential pressure created in the pumping main by introducing a venture-flume or an orifice plate. Air release cock is provided at the top to release the air during each loading of the rubber bag with bleaching powder solution. The chlorine solution is prepared using bleaching powder and allowed to settle for a period of about 20 to 30 minutes to settle down. The clear decanted solution is filtered and filled into the rubber bag. When the pump starts due to high pressure developed prior to the orifice plate, water enters into the gap between the rubber bag and the tank and starts compressing the rubber bag. Due to this the solution in the rubber bag rises and is injected into the pumping main beyond the orifice plate where the pressure is reduced. When the pump set is put off the non-return valve in the outlet pipe prevents the entry of water into the rubber bag. The dosage shall be adjusted to dispense the solution completely during the design pumping hours.

- **Comparison of Various Disinfection Systems**

TABLE 7.5

Sl No	Parameters	Silver Ionization	Chlorination	UV radiations	KMNO ₄
1	Harmful to Eyes?	No	Yes	Yes	Yes
2	Irritating to skin?	No	Yes	Yes	Yes
3	Bleaching hair?	No	Yes	Yes	No
4	Explosive, unsafe?	No	Yes	No	Yes
5	Dangerous to store?	No	Yes	No	Yes
6	Corrosive to pipelines?	No	Yes	Yes	Yes
7	Evaporates?	No	Yes	No	No
8	Toxic to landscaping?	No	Yes	No	Yes
9	Unpleasant smell?	No	Yes	No	Yes

- Hard water creates serious troubles in the manufacturing process of textile, finishing, paper-making dyeing, rayon industry, canning, ice-making etc.,
- Hard waters choke and clog plumbing due to precipitation of salts in them.

7.15. Selection and Design of Water Treatment Plants

The concept of reliability and maintainability has yet to gain significant importance as design parameter. Plants thus become less efficient with passage of time. The life of water treatment plant may be 50-60 years and equipment life may be 10-20 years. It is necessary to design and construct reliable and maintainable plant so that the desired out-put is obtainable throughout the life of the plant.

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- Flow Measurement: A general defect with flow measurement devices is the turbulence of flow near the point of measurement. An adequate stilling basin should always be provided before measuring chamber to suppress the turbulence.
 - Aeration: Aeration is necessary only in case of ground water containing ferrous iron or water drawn from deep reservoirs and having odour difficulties. River waters seldom call for aeration. In some cases, aeration may even cause harm by raising pH value above the optimum for alum coagulation.
 - Chemical Dosing: The chemical house is generally two storey structure. Chemicals are stored in ground floor and the chemical solution is prepared in upper floor at a level high enough to command the raw water channel by gravity. Two storey arrangements are suitable only for small and medium plants. In case of large plants it will be better to have the solution tank at ground floor itself to avoid the need for lifting up large quantities of chemicals and also reduce the cost of structures.
 - Flocculation: The advantage of mechanical flocculation is that the speed of agitation can be varied to suit water quality but most of the mechanical flocculators are not provided with variable speed devices. Such being the case, mechanical flocculation may not be justified for small plants.
 - Sedimentation Tanks: Before acceptance of offer, each aspect of the design parameters of the settling tank should be checked. However certain practical problems with regard to sedimentation tanks are to be considered in detail.
 - Filters: One important aspect in filter design is the filter depth. There is a tendency to reduce this depth so as to save on the filter box cost. Filters with as little as 0.9 m depth of water over sand have been accepted. Reduced water depth will increase negative head on the sand, which in turn will increase air binding of the filter and cause mud ball formation and give poor effluent. The depth of water in no case should be less than 1 m preferably 1.5 m.
 - Other Features:
 - Filter Valves: These are subject to heavy wear and tear as they are operated several times a day. The valves should be sturdy and of reputed type irrespective of cost.
 - Over load Capacity: It will be prudent to size raw water channel and the inlet and outlet piping of flush mixer, the flocculation tank and settling tank for an over load of 100% to take care of increased demand.
 - Sanitary inspection covers: In case, walk way is placed over the filtered water channel, it would be ensured that all inspection covers over the filter outlet chamber and filtered water channel are of sanitary over lapping type to avoid any dust and dirt entering in the filtered water channel through the inspection cover.
 - Accuracy of filter rate controller: It is perhaps the costliest fitting in the filter. Its design should be examined critically and the offers of equipment should not be accepted at face value.
 - Performance Guarantee: The usual practice to demand performance guarantee from tenderers covers final water quality and wash water requirements and verified during an initial 90 days operation of the plant by tenderers.

7.16. Priority Levels of Technical Options for Water Quality

The priority level for treatment of various constituents like fluorides, nitrates, total dissolve solids, iron and coli form bacteria are shown in table 7.6.

TABLE 7.6

Sl. No.	Parameter	Available options	Accepted/ Recommended Options in order of priority
1.	Fluoride	a. Alternate local / distant ground water source (with appropriate ground water recharge arrangements) b. Local/distant surface source c. Blending with non-fluoride water wherever feasible d. Dual supply with different service level (drinking, cooking and other purposes) e. Household defluoridation units f. (i) Nalgonda technique (using Alum). (ii) Ion Exchange process (using activated alumina)	a. Where isolated small number of habitations are affected. b. Where large number of contiguous villages are affected c. Where fluoride concentration is marginally higher (1.5-2 mg/l) and fluoride free water is available. d. Where community is aware and able to distinguish the difference (on pilot basis) e. Can be tried on an experimental basis f. Can be tried on an experimental basis
2.	Nitrate	a. In areas affected with nitrate, open well sources shall be avoided. b. Alternatively, bore well with atleast 10 metres casing is recommended. Flushing is to be done first, before commissioning the supply.	a. In areas affected with Nitrate, open well sources shall be avoided. b. Alternatively bore well with a minimum of 10 metres casing is recommended. Flushing is to be done first.
3.	TDS	a. Alternate distant source/ ground water b. Alternate local/distant surface source. c. Blending, if possible	a. Alternate distant source/ ground water b. Alternate local/distant surface source. c. Blending, if possible.
4.	Iron	a. Treatment for iron removal. b. Regular use of bore wells to avoid accumulation of corrosion products from iron pipes.	a. Creating awareness to avoid long idling of bore wells. b. Store water longer and strain through cloth. c. Change the MS pipe to PVC pipe casing. d. Use PVC pipe for new bore holes
5.	Bacteria (Coliforms)	a. Disinfection	a. Continuous chlorination of water supply to maintain a minimum residual concentration of 0.2 mg/l.

7.17. Defluoridation of Water

Excessive fluorides in drinking water may cause mottling of teeth or dental fluorosis, a condition resulting in the discoloration of the enamel, with chipping of the teeth in severe cases, particularly in children. In Indian conditions where the temperatures are high, the occurrence and severity of mottling increases when the fluoride levels exceed 1.0 mg/l. With higher levels, skeletal or bone fluorosis with its crippling effects are observed. The chief sources of fluorides in nature are (i) fluorapatite (phosphate rock), (ii) fluorspar, (iii) cryolite and (iv) igneous rocks containing fluorosilicates. Fluorides are present mostly in ground waters and high concentrations have been found in various districts of Andhra Pradesh. While majority of values range from 1.5 to 6.0 mg /l, some values as high as 16 to 18 mg/l have been reported.

Removal Methods.

The removal of excessive fluorides from public water supplies or individual water supplies is justifiable solely on public health grounds. This is a problem particularly in rural areas and hence the emphasis has to be on simplicity of operation, cheapness and applicability to small water supplies. The methods are fluoride exchangers like tricalcium phosphate or bone meal, anion exchangers, activated carbon, magnesium salts or aluminum salts.

1. Fluoride Exchangers

Degreased and alkali treated bones possess the ability to remove fluorides but have not been used on a plant scale. Bone charcoal prepared by controlled combustion of bones under limited supply of air in the presence of catalysts when treated with alkali or phosphate has been found to be useful. One cubic meter of bone charcoal is capable of removing 1.1 kg of fluoride from water with fluoride content up to 6.0 mg/l. The spent material can also be used but it has a lesser capacity of 0.7 kg of fluoride / m³. The spent material is regenerated by treatment with 1% alkali solution and rinsed with dilute hydrochloric acid.

2. Anion Exchangers

Activated carbons have also been known to have the capacity for removal of fluorides. An activated carbon for fluoride removal has been developed in India by carbonizing paddy husk or sawdust, digesting under pressure with alkali and quenching it in a 2% alum solution. This could remove 320 mg of fluoride per kilogram of the dry material. The spent material could be regenerated by soaking it in a 2% alum solution for 14 hours. The attrition and hydraulic properties of the carbon are however poor.

A granular ion-exchange material Defluoron 2, which is a sulphonated coal operating on the aluminum cycle has been developed in the country. The capacity of the material is estimated to be 500 gm of fluorides/m³ with test water containing 5 mg F/l and 150 mg/l alkalinity. The regeneration is carried out by means of a 2.5% alum solution, with replacement of two bed volumes. A flow rate of 4.8m³/m²/hr of bed area is adopted. The rinse water requirements after regeneration are 9-12 m³/m²/hr for a maximum duration of 10 minutes. The medium has a life of three years.

High alkalinity of the water considerably lowers the capacity as well as efficiency of the bed. Hydroxyl alkalinity beyond 5 mg/l has a deleterious effect on the removal efficiency of the medium. The efficiency of the medium falls down by 30% when hydroxyl alkalinity becomes 25 mg/l.

Magnesium Salts

Excess lime treatment for softening effects removal of fluoride due to its adsorption by the magnesium hydroxide floc. The fluoride reduction is given by the following formula

$$\text{Fluoride reduction} = 7\% \text{ initial fluoride concentration} \times \sqrt{\text{Magnesium removed}}$$

Sizeable fluoride removals are possible only when magnesium is present in large quantities, which may not always be the case and the magnesium has to be supplemented in the form of salts. The process is suitable only when the water is being softened

Aluminum Salts

Aluminum salts like filter alum and activated aluminum and alum treated ion exchangers have shown beneficial effects. Filter alum during coagulation brings about some removal of fluorides from water. The removal efficiency is improved when used along with a coagulant aid-like activated silica and clay. 300 to 500 mg/l of alum is required to bring down fluoride from 4.0 mg/l to 1.0 mg/l while with coagulant aid, the fluorides were reported to be reduced from 6.0 mg/l to 1.0 mg/l with alum dose of only 100 mg/l.

Alum treated polystyrene cation exchangers and sulphonated coals have also been used successfully. A cation exchanger prepared from extract of Avaram bark and formaldehyde when soaked in alum solution has been found to have good fluoride removal capacity (800 mg/Kg.)

Calcinated or activated alumina in granular form can be used for fluoride removal and the spent material regenerated with alkali, acid or by both alternately (removal efficiently 1.2 Kg of fluoride/m³). A dilute solution of aluminium sulphates used as the regenerant for the spent material makes the alumina four times more efficient.

Simple Method of Defluoridation

Defluoridation is achieved either by fixed bed media which could be regenerated or by the process of precipitation and formation of complexes. A simple method of defluoridation is employed in the Nalgonda Technique. It involves the use of aluminium salts for the removal of fluoride. The Nalgonda Technique employs either the sequence of precipitation, settling and filtration or precipitation, floatation and filtration and can be used for domestic as well as community water supply schemes.

Domestic Treatment – Precipitation, Settling and Filtration

Treatment can be carried out in a container (bucket) of 40 lts capacity with a tap 3-5 cm above the bottom of the container for the withdrawal of treated water after precipitation and settling. The raw water taken in the container is mixed with adequate amount of lime or sodium carbonate, bleaching powder and aluminum sulphates solution, depending upon its alkalinity and fluoride content. Lime or sodium carbonate solution is added first and mixed well with water.

Alum solution is then added and the water stirred slowly for 10 minutes and allowed to settle for nearly one hour. The supernatant which contains permissible amount of fluoride is withdrawn through the tap for consumption. The settled sludge is discarded. The amount of alum in ml to be added in 40 litres of water at various alkalinity and fluoride level is given in table 7.7.

Alum Dose for Different Fluorides and Alkalinity Levels

TABLE 7.7

Test Water Fluoride mg	Test water alkalinity mg CaCO ₃ /l							
1	125	200	300	400	500	600	800	1000
2	60	90	110	120	140	160	190	210
3	90	120	140	160	205	210	235	310
4		160	165	190	225	240	275	375
5			205	240	275	290	355	405
6			245	285	315	375	425	485
8					395	450	520	570
10							605	675

7.18. Reverse Osmosis

Osmosis: Certain natural and synthetic membranes have the property of permitting the solvent (water) to get through them, but not the solute. Such semi permeable membranes permit the separation of solute and solvent. This phenomenon is known as ‘Osmosis’. A Schematic Diagram of Reverse Osmosis is shown in Fig.7.20.

Reverse Osmosis: Reverse Osmosis is a membrane permeation process for separating relatively pure water from less pure water. The solution is passed over the surface of an appropriate semi permeable membrane at a pressure in excess of the effective osmotic pressure of the feed water. The permeated water is collected as the product and the concentrated solution is generally discharged. The membrane must be highly permeable to water, highly impermeable to solutes and capable of withstanding the applied pressure without fail.

Advantages: Removal of all types of contaminants including fluoride, total dissolved solids and bacteria.

Fluoride Concentration: The presence of fluoride in the range 1.0 – 2.0 mg/litre is the optimum beneficial concentration of fluoride in drinking water for dental protection, more than that causes health concerns.

Technical Specifications and process details:

- The Plant should be designed based on the following Raw Water properties.
 - Total Dissolved Solids (TDS) : upto 5000 ppm
 - Total Hardness : upto 1000 ppm as CaCO₃
 - Fluorides : upto 1.5 ppm
- The components of Reverse Osmosis Plant:

Raw water storage tank	Raw water is fed into this tank.
Raw water pump	To pump raw water into the inlet of dual media filter.
Dual media filter with filter mesh	Suspended impurities present in raw water are removed.
Activated Carbon filter	Water goes through the Activated Carbon filter in which odour & color are removed. The hardness of the water is removed to prevent membrane scaling due to calcium carbonate and calcium sulfate salts.
Cartridge filter	The water passes through cartridge filter to reduce the SDI below acceptable limits for the R.O membrane that is 4. The cartridge

	also takes care of presence of any foreign particles and prevents it from going into the pressure pump to prevent any damage to the pump.
High pressure pump	It pumps water at high pressure through R.O block.
R.O Block	The major quantity of dissolved salts is rejected with rejected stream and almost pure water comes out as separate stream.
U.V Sterilizer	The permeate water shall be collected in a blending tank where activated carbon filter water will be mixed to bring the water quality as per the required specification.
Product storage tank	Collects the treated water.

The TDS of water shall be reduced to a major extent in the R.O section. The treated water quality expected out of R.O section shall meet BIS Standard for drinking water.

The quality expected is as follows.

TDS	<	50 ppm
Hardness	<	5 ppm
Fluorides, iron, heavy metals	<	0.9 ppm

7.19. Pressure filters

Based on the same principle as gravity type rapid sand filters, water is passed through the filter under pressured through a cylindrical tank, usually made of Fibre Glass with single valve operation. Wherein the under drain, gravel and sand are placed. They are compact and can be prefabricated and moved to site. Economy is possible in certain cases by avoiding double pumping pretreatment is essential. The tank axis may be either vertical or horizontal.

Salient Features:

- It shall have single valve operation for Back Wash, Recirculation, Rinse, Filter Waste close to eliminate leakage from individual valves.
- Give visual indication as to the present operation of the filter.
- It shall have Multi port valve with quick connect threaded barrel unions.
- It shall have hydraulically balanced laterals to maximize water flow and automatic air bleed.
- Tank of the pressure sand filter shall be made of Fibre Glass

Disadvantages

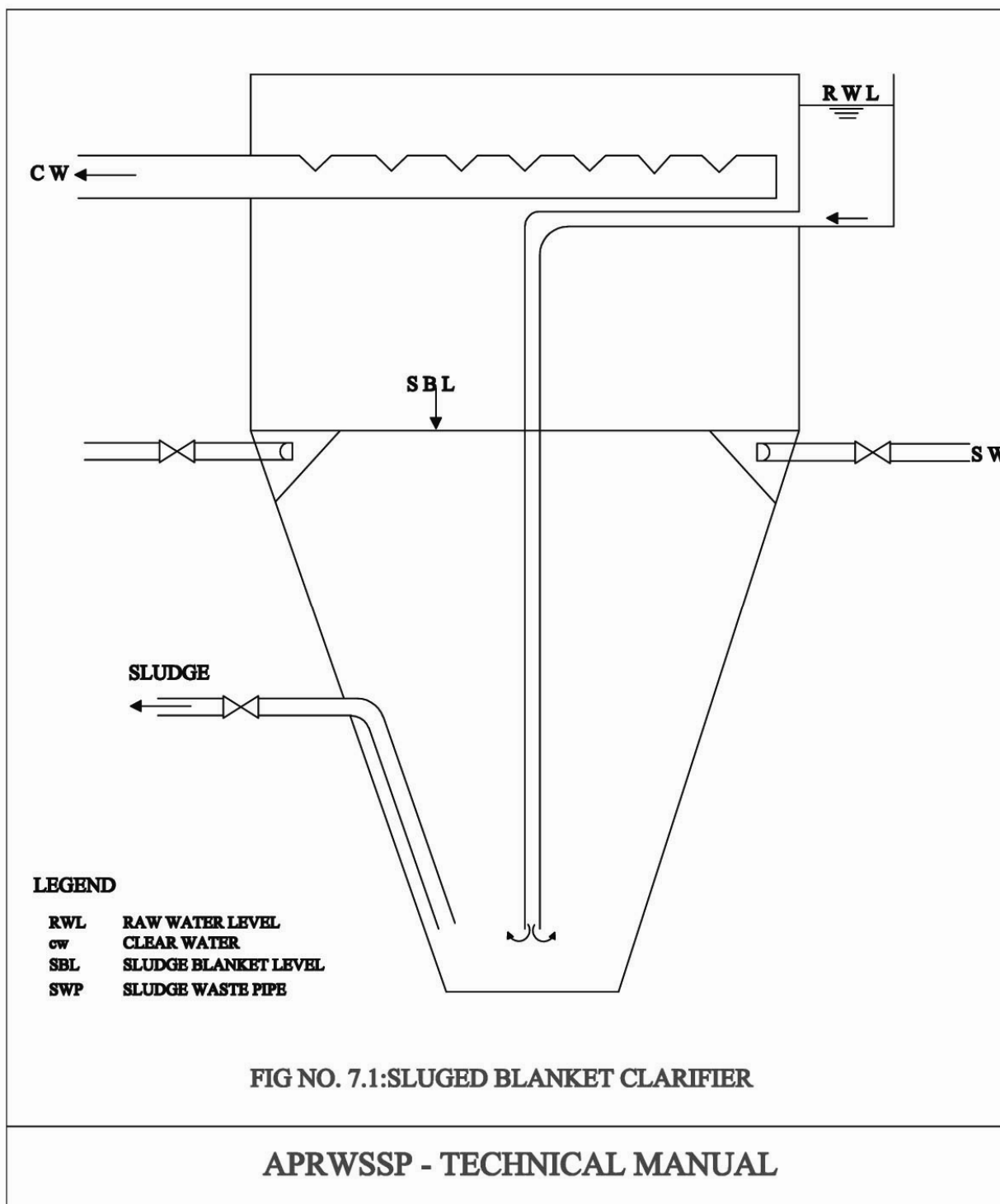
- In case of direct supply from pressure filters, it is not possible to provide adequate contact time for chlorine.
- Because the water is under pressure at the delivery end, on occasions when the pressure on the discharge main is released suddenly, the entire sand bed might be disturbed violently with disastrous results to the filter effluent.

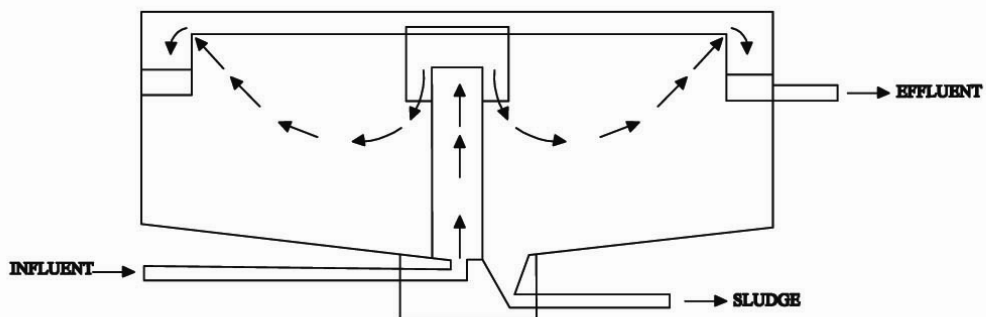
They may be used for Single Village Schemes where population is less as traditional canal based scheme may be very expensive for small communities.

7.20. Micro filters

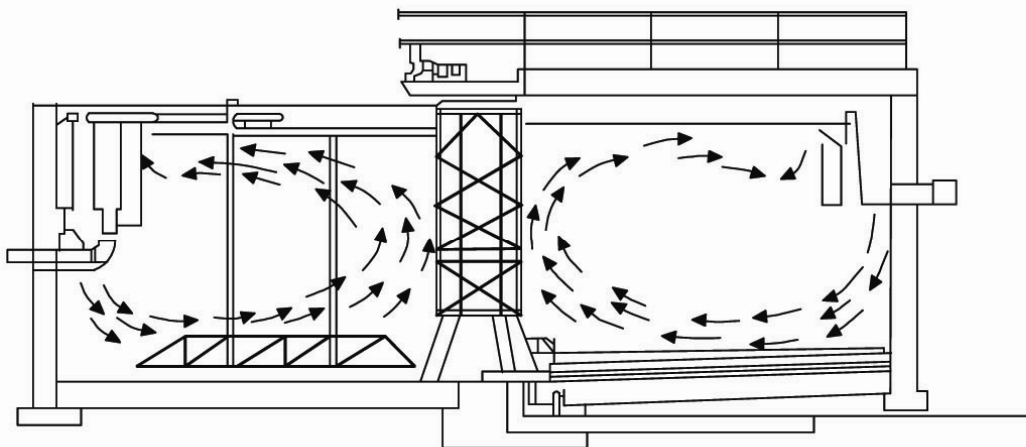
Micro filters are small-scale filters designed to remove cysts, suspended solids protozoa, and in some cases bacteria from water. Micro filtration is a filtration process, which removes contaminants from a fluid (liquid and gas) by passing through a micro porous membrane of pore size range from 0.1 to 10

(micro m). Micro filtration is not fundamentally different from reverse osmosis except in terms of the size of the molecules it retains. Most filters use a ceramic or fiber element that can be cleared to restore performance as the units are used. Most units are made for camping use a hand pump through the filter. Others use gravity, either placing the water to be filtered above the filter (e.g. the Katadyn drip filter) or by placing the filter in the water, and running a siphon hose to a collection vessel located below the filter.

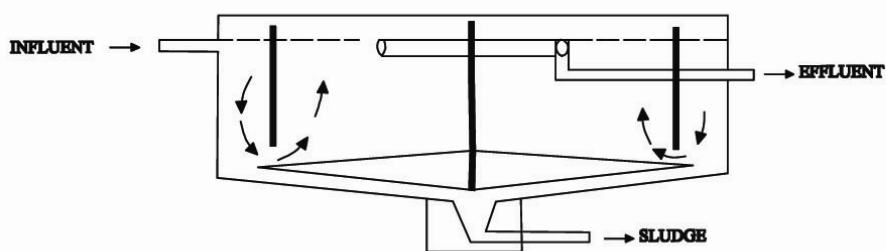




CIRCULAR CLARIFIER WITH CENTRE FEED



**PERIPHERAL FEED CIRCULAR CLARIFIER WITH EFFLUENT
CHANNELS SEPARATED BY A SKIRT**



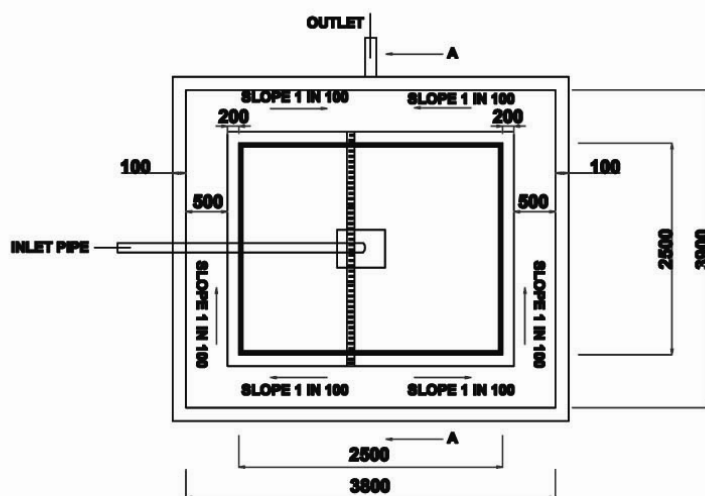
PERIPHERAL FEED CIRCULAR CLARIFIER WITH EFFLUENT WEIRS NEAR OF BASIN

FIG NO. 7.2 : VARIOUS TYPES OF CIRCULAR CLARIFIERS

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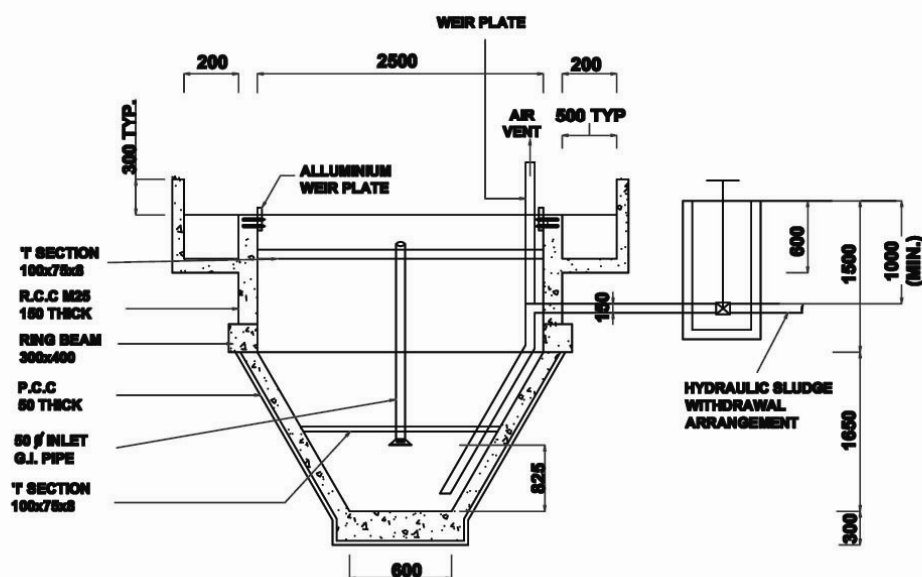
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PLAN

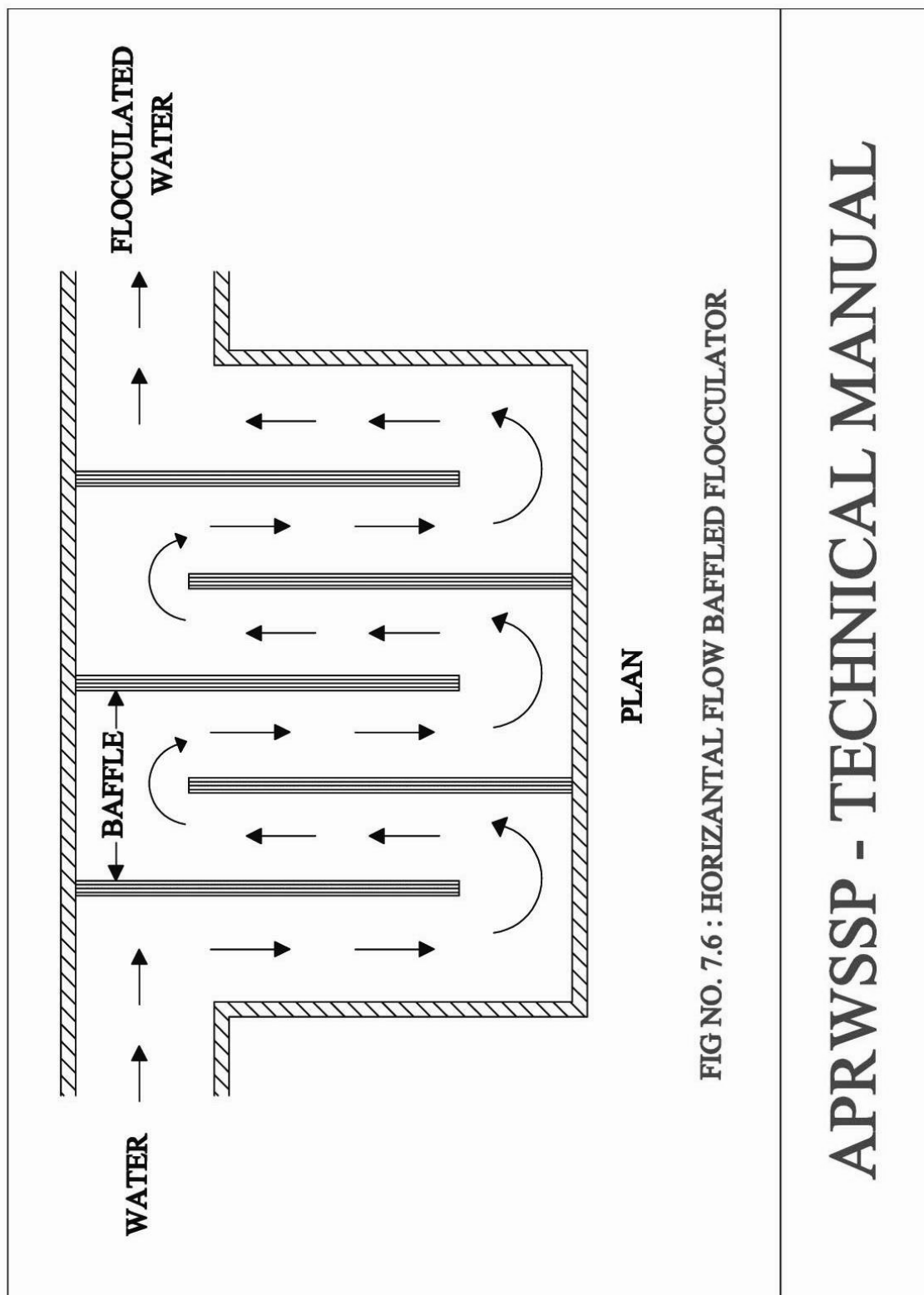
NOTES :

1. DUE TO DECREASE IN UPFLOW VELOCITY PARTICLES SETTLEMENT WILL BE MORE EFFECTIVE IN HOPPER PORTION.
2. SLUDGE SLIDING ALONG THE HOPPER WALL WILL BE MORE EFFECTIVE.
3. SLUDGE COLLECTIONS AT CORNERS WILL BE AVOIDED & WITHDRAWAL WILL BE EASIER.
4. ALLUMINIUM WEIR IS PROVIDED TO TAKE CARE THE CONSTRUCTION TOLERANCE IN THE SIDE WALL AND HELPS IN UNIFORM OVERFLOW THROUGHOUT THE PERIPHERY AND TO AVOID DEAD ZONES.

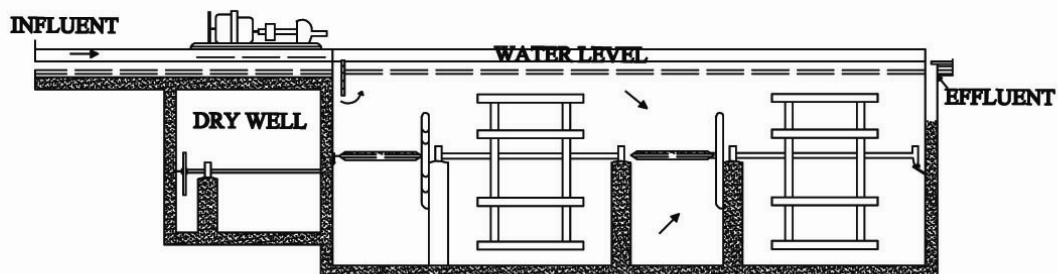


SECTION : A-A

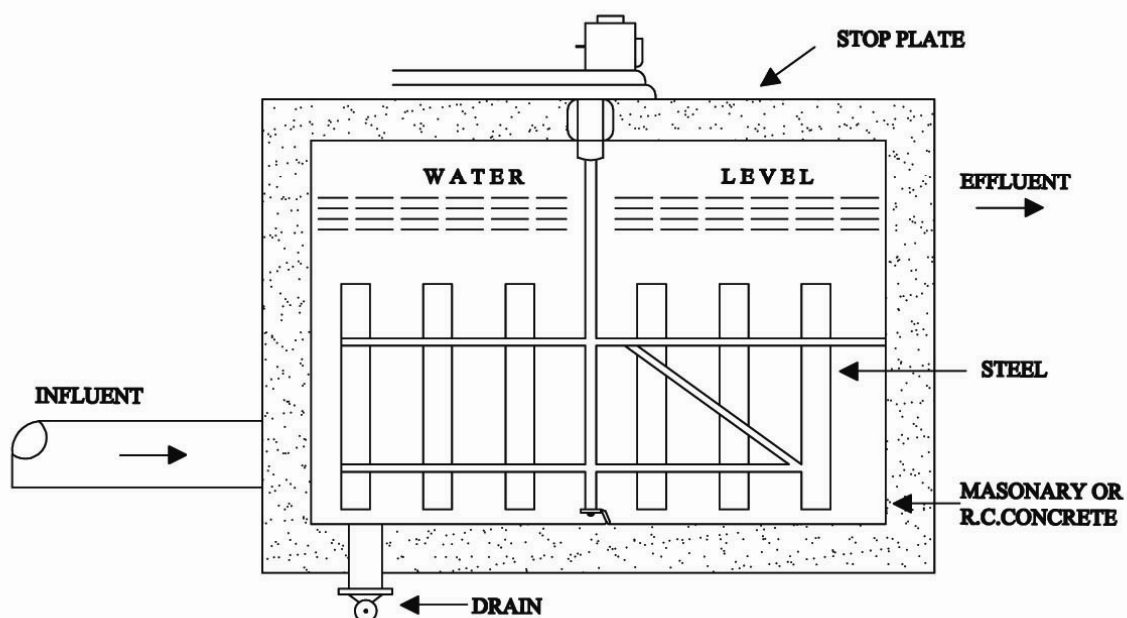
FIG NO. 7.5 : HOPPER BOTTOM SETTLING TANK



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Flocculator Longitudinal Flow



Vertical Flocculator

FIG NO. 7.7 : Mechanical Flocculator With Paddles

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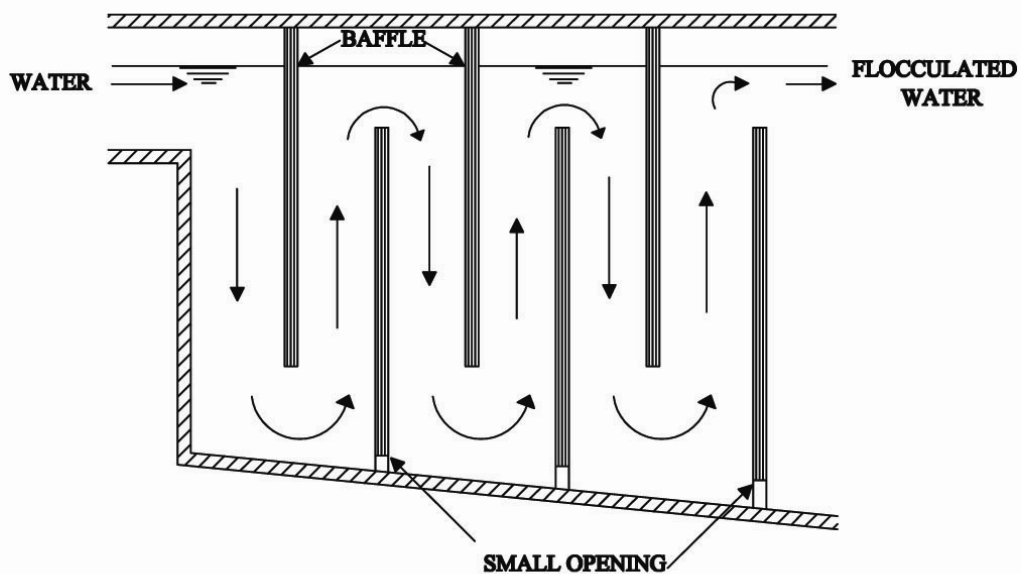


FIG NO. 7.8 : VERTICAL FLOW BAFFLED FLOCCULATOR

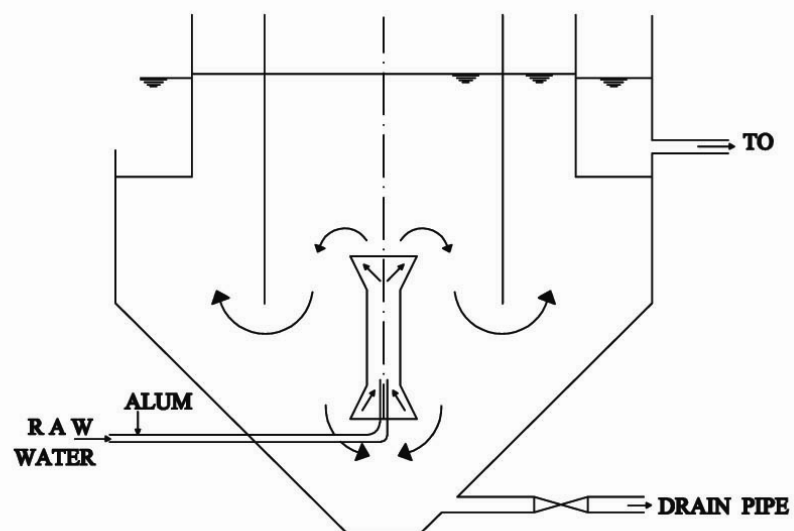
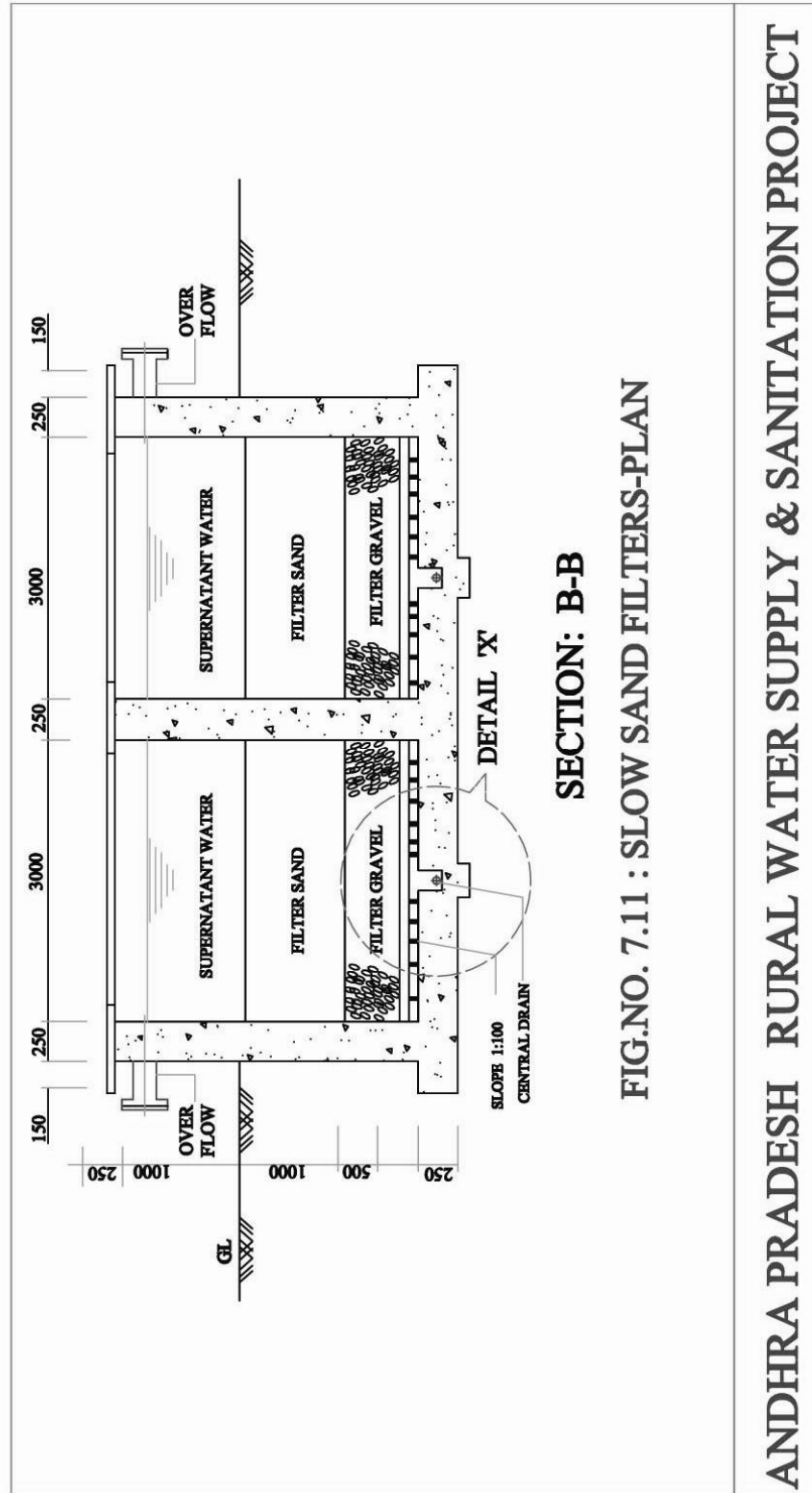


FIG NO. 7.9 : JET FLOCCULATOR

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ANDHRA PRADESH RURAL WATER SUPPLY & SANITATION PROJECT

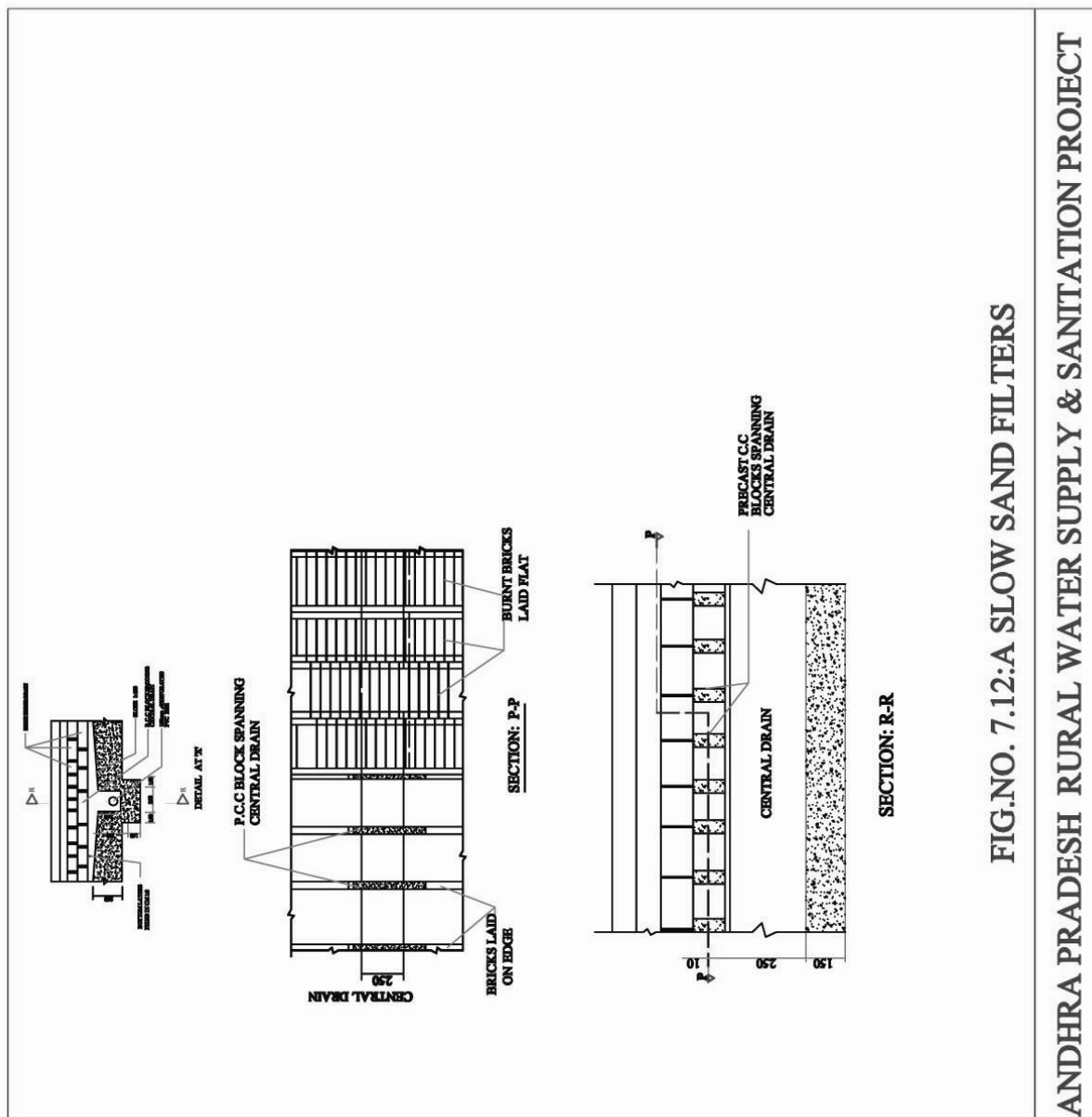
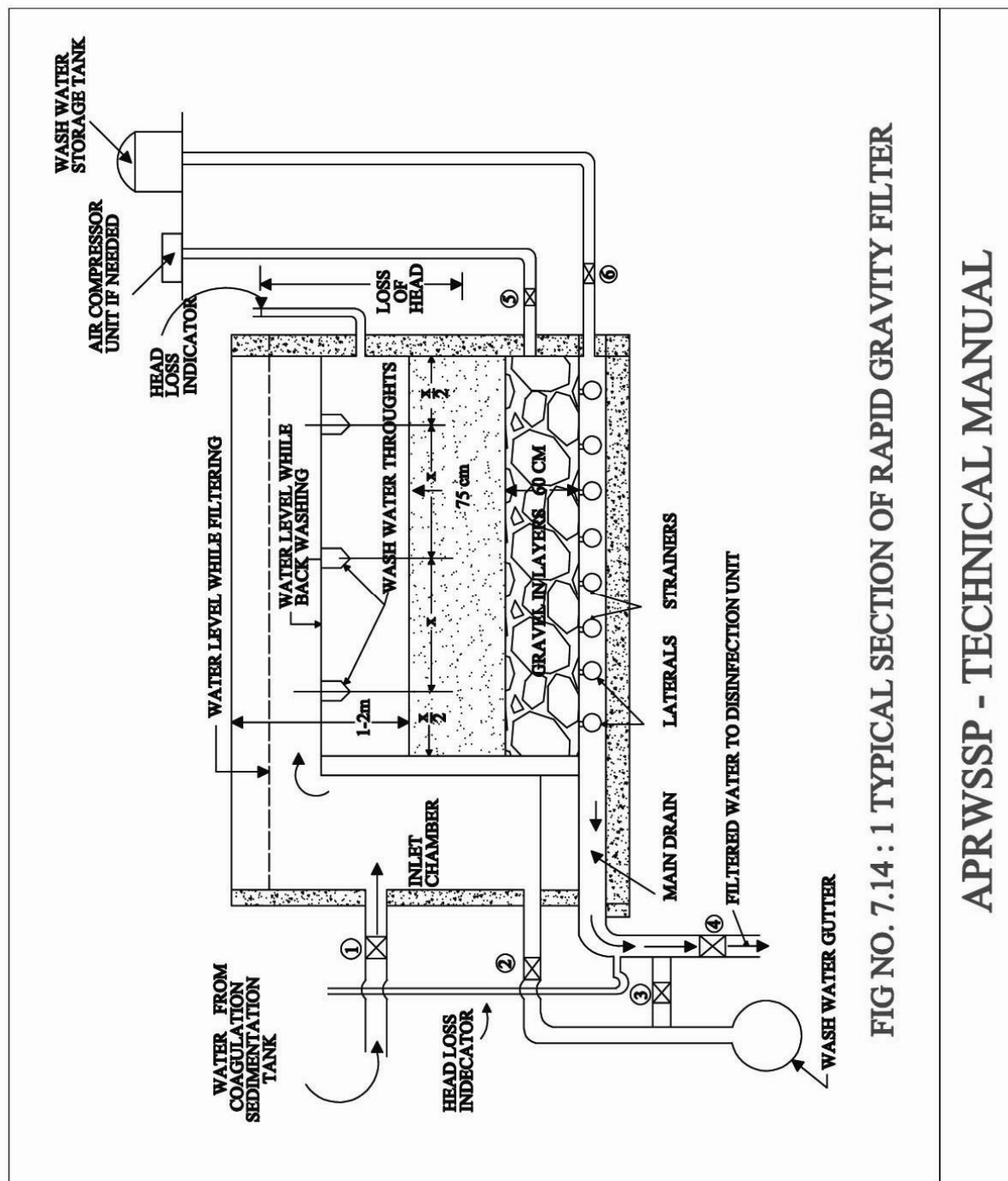
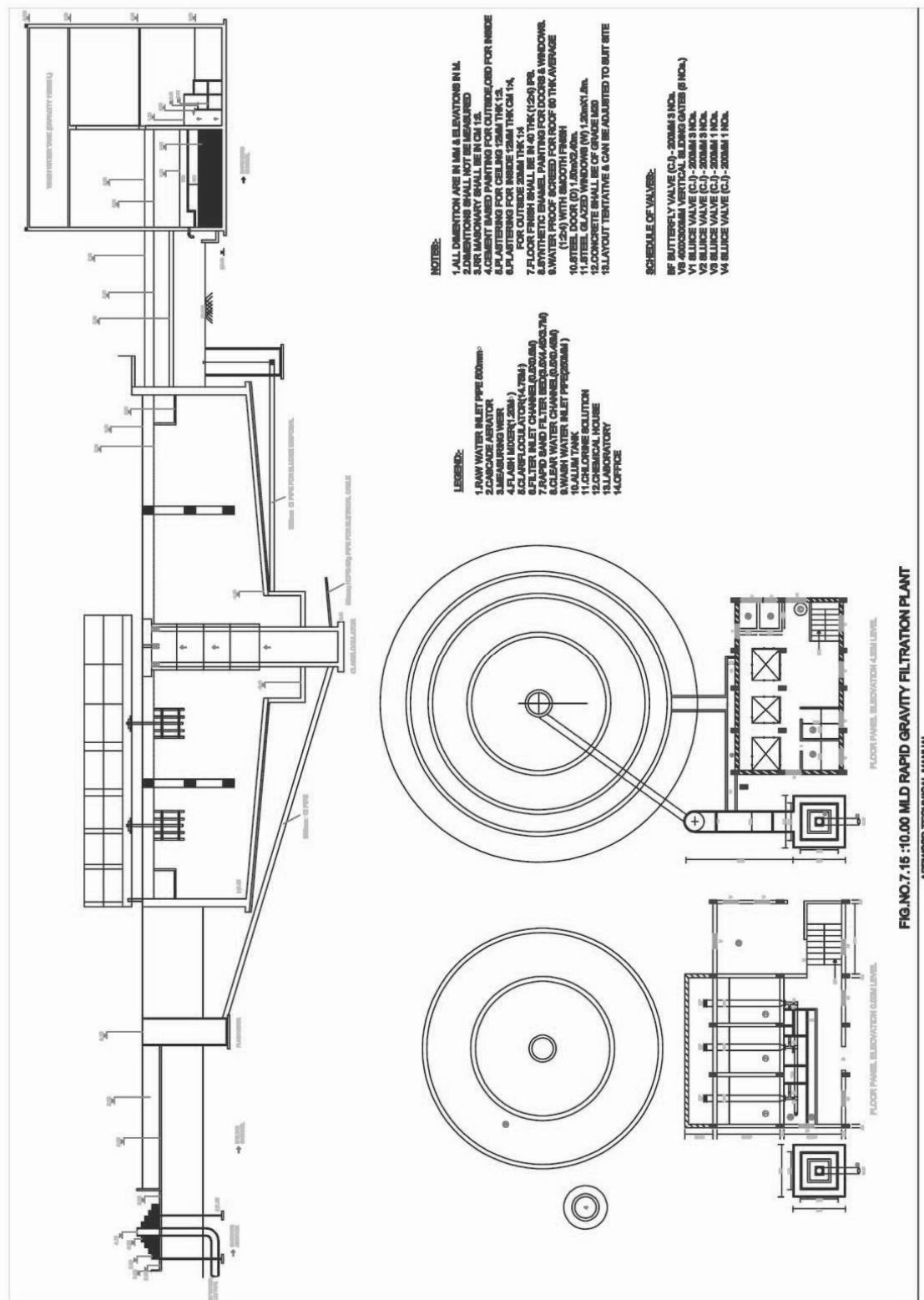


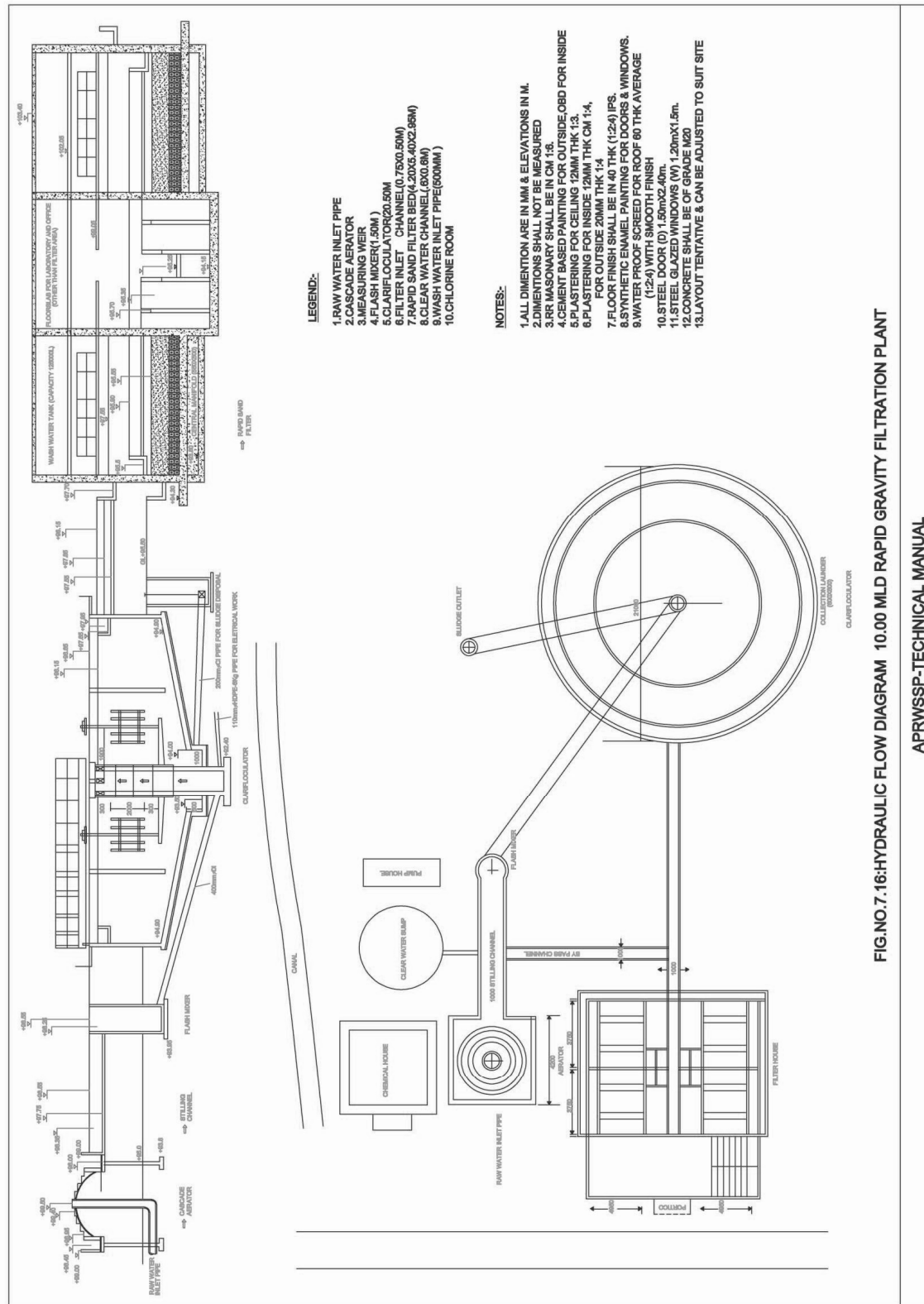
FIG.NO. 7.12:A SLOW SAND FILTERS

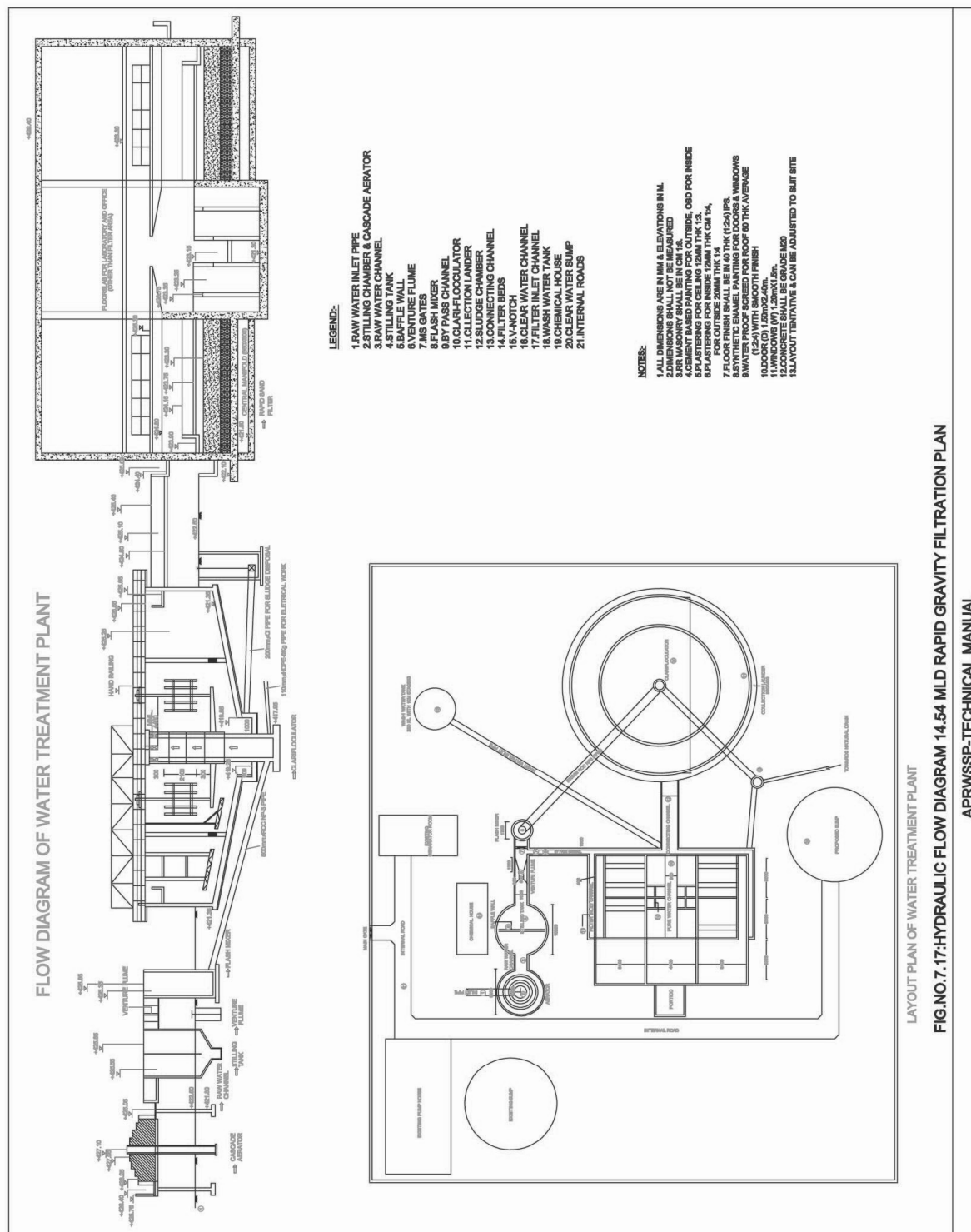
ANDHRA PRADESH RURAL WATER SUPPLY & SANITATION PROJECT

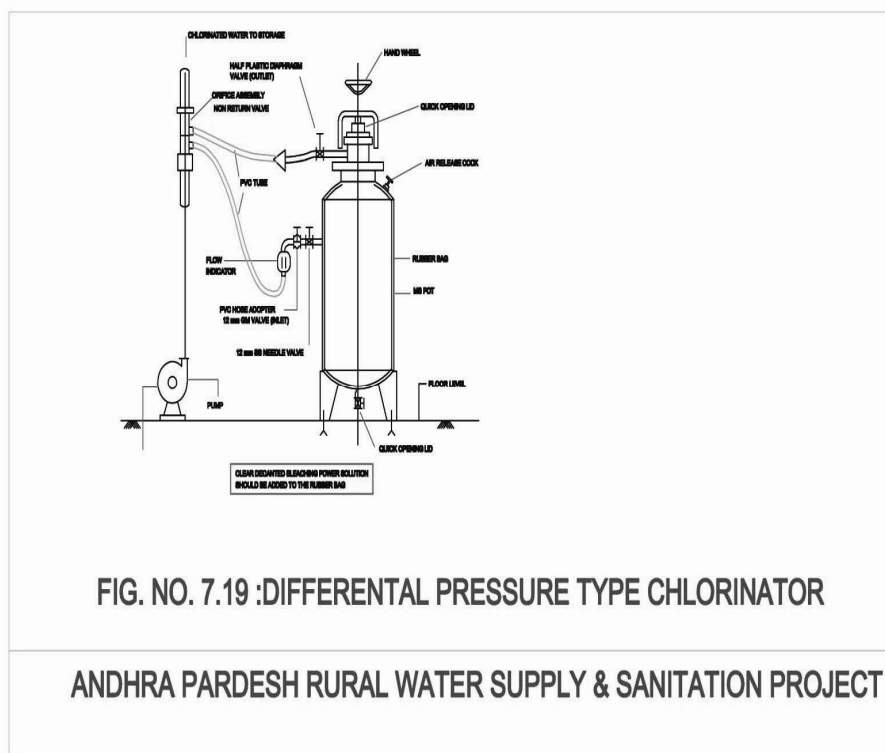
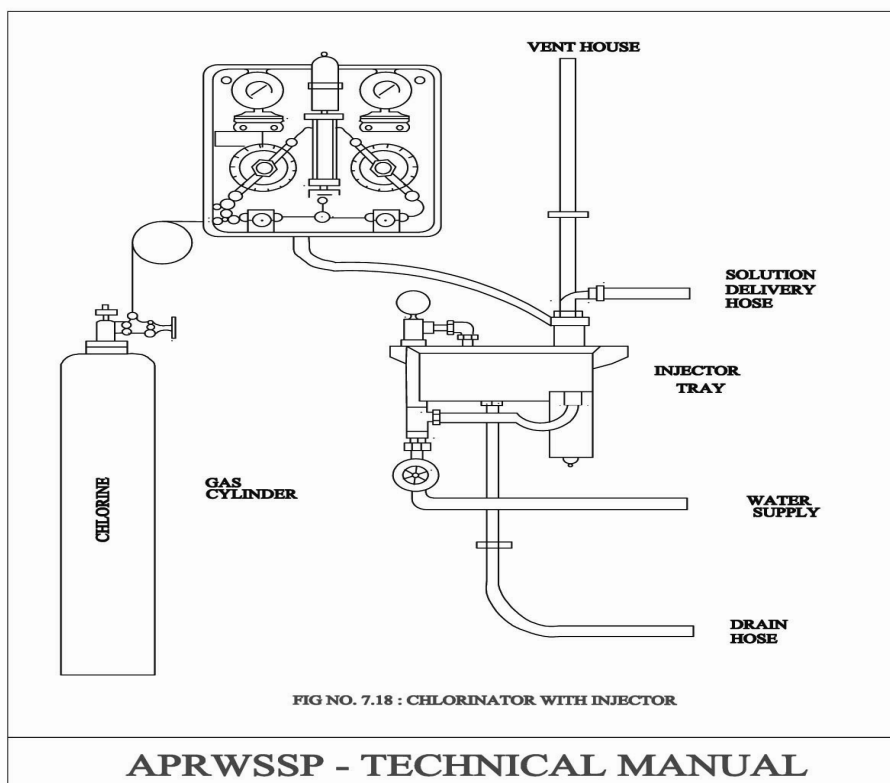


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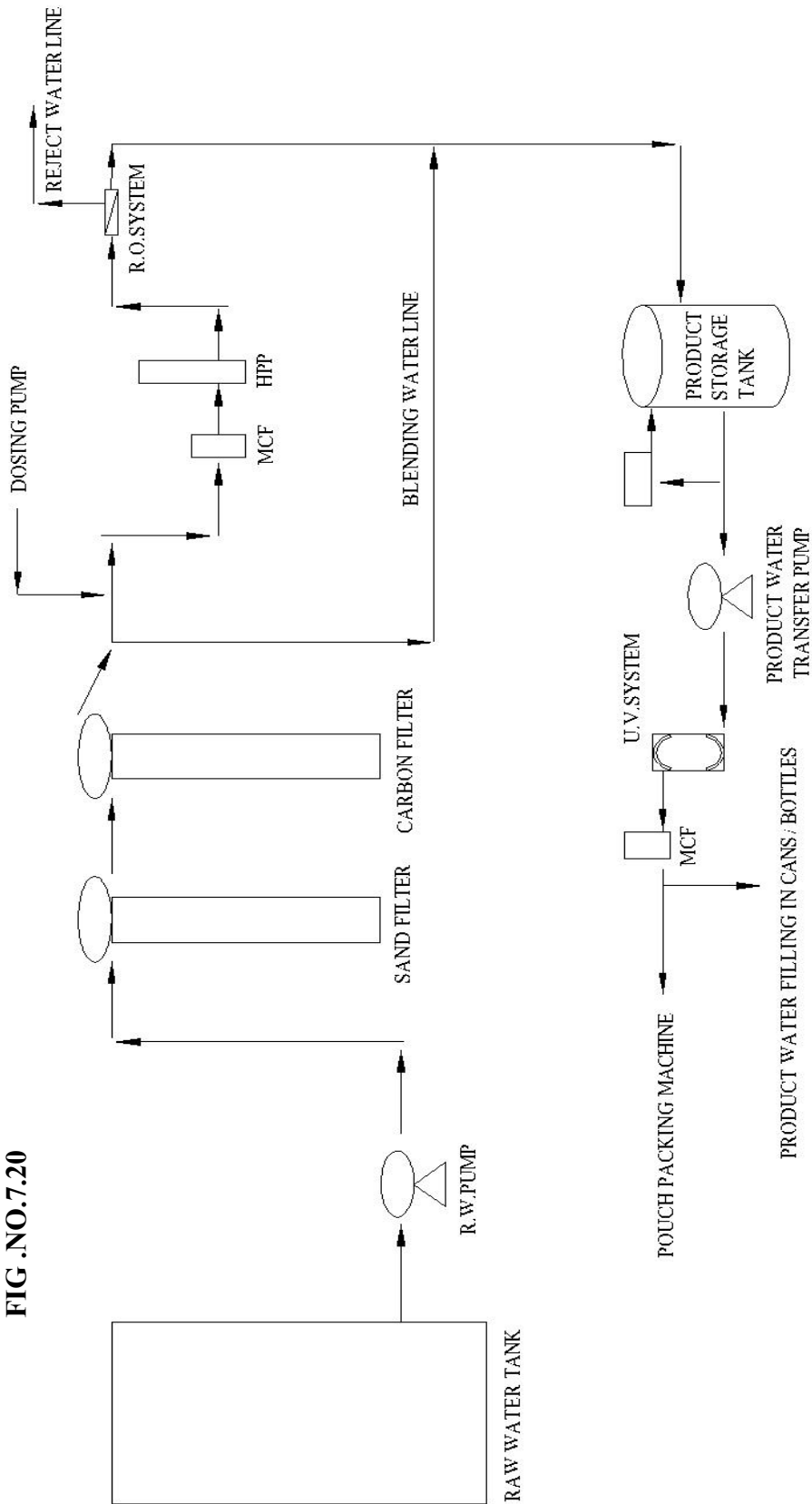






RO SYSTEM SCHEMATIC FLOW DIAGRAM

FIG .NO.7.20



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CHAPTER – 8

8. SERVICE RESERVOIRS

Reservoirs are structures which are built at any convenient point in the distribution between the original source and the consumer end. The function of the reservoir varies considerably depending upon their type and need. The general functions of a reservoir are detailed below:

- To equalize the rate of flow, adjusting a variable demand rate to the rate of supply not equal to it. This allows the pumps to work at a steady constant rate which not only improves their efficiency but also reduces the cost of their operation and maintenance.
- To equalize pressure and to make it possible to pump water at an average constant head and thereby reducing the size of the pump and also pumping cost, since peak pressures are taken over from the pump.
- To provide and maintain the desired pressure in remote areas.
- To provide necessary time for sedimentation and also contact time for chlorine disinfection.
- To store water for emergencies such as fires and break-down periods.
- To provide economy and safety to the distribution system.
- The pumping can be carried out in shifts and during hours convenient to the operating personnel and availability of power.
- To carryout any repairs to the conveying mains between the source of supply and the reservoir without interruption of water service.
- Balancing tank at the end of distribution system with a nominal capacity of 1 or 2 hours where direct pumping into the distribution system is adopted for acting as relief valve. For such arrangements Ground Storage tanks are used for direct pumping which involves a suction head.

8.1. Type of Reservoirs used in rural water supply

- Ground Level Service Reservoir (GLSR): They are generally of masonry, R.C.C. steel and earth.
- Over Head Service Reservoir (OHSR): These are also generally made of R.C.C. and Steel.

When the reservoirs need not be over head, it is most economical to adopt ground level reservoirs. Where treated water is to be stored, these reservoirs are usually built with masonry walls and may be completely under ground or partially under ground depending upon the topography of the locality. Ground level reservoirs are usually covered, unless very large in area. The cover protects the water against contamination from wind borne material, birds and other sources, and it also prevents growth of algae and other plant life which might affect the taste and appearance of water.

Over head reservoirs are generally costly and are provided only if the ground level reservoirs cannot provide the required pressure in the distribution system. Storage of water in over head tanks located at strategic points throughout the distribution system is usually necessary, unless the terrain is hilly enough to permit the use of ground level tank to maintain desired pressure in the distribution system. A low level reservoir is of service only in equalizing the operations of filters, deep well pumps, low lift pumps and conduits bringing water from a distant source. High level reservoirs act as equalizers to the entire supply system, including pumps and some of the distributing mains.

In Multi Village schemes Over Head Balancing Reservoir (OHBR) is provided at head works site to collect treated water from sumps and transfer to different OHSRs in villages for distribution. OHBR is only for providing head and not for distribution purpose. In Multi Village schemes raw water sump and clear water sumps are also provided.

8.2. Location of Reservoirs

The three possible locations of Reservoirs are:

- i) Locating the reservoir in central point with respect to distribution area. This will reduce the size of distribution mains and will cause better equalization of flow during peak demand periods. More uniform pressure will prevail in the system.
- ii) Locating near the beginning of the system. This is adopted where the distribution area is at a lower level compared to the general alignment of pumping main. Then the length of the pumping main becomes shorter, but the length of the distribution system mains becomes more.
- iii) Locating the reservoir site at a suitable altitude. It depends on the availability of land at suitable altitudes. It is necessary that bottom water level shall be at such a height that allows for frictional losses in the distribution mains and required residual head in any part of the system. This can be ensured either by locating the reservoir on high ground or by building on a tower.

8.3. Capacity of Reservoirs

While designing the storage of a reservoir, the first consideration is the capacity which will be provided. To great extent this depends upon the type of supply and is influenced by two main factors – the necessity of catering for peak demand periods and the provision of reserve to cover normal break down or maintenance interruptions.

In case water is supplied to the village by gravity from the source located a higher level, it is most economical in capital cost, as well as most satisfactory from an operational aspect, if the flow is designed to be maintained through out 24 hours. In such a case, obviously a smaller dia pipe is enough. One shift of eight hours, or totaling sixteen hours, is a frequent method of operation. It is very common to find the schemes designed to operate with a single shift of eight hours initially, increasing to 16 hours when the demand rises later. More than 16 hours is not desirable. The minimum capacity of the service reservoir is the sum of maximum surplus and maximum deficit values in between the commutative pumped water into the tank and outlet due to the demand of population. Town with similar nature can provide required information on variation of demand in a day which depends upon the supply hours.

The following figures can, however, provide a fairly good idea of the demand pattern for small towns and villages, the demand pattern will be as follows:

7.00 AM – 8.00 AM	=	30% of average Daily demand.
8.00 AM – 5.00 PM	=	35% “
5.00 PM – 6.30 PM	=	30% “
6.30 PM – 7.00 AM	=	5% “

Where it is an intermittent supply system, the demand pattern will largely depend upon the number of hours of pumping which, of course, takes into account the periods of peak demand.

For 8 hours a day	...	3 times average hourly demand
For 6 hours a day	...	4 times average hourly demand
For 12 hours a day	...	2 times average hourly demand

Shape of Reservoirs

The shape of reservoirs selected should be economical and the length of retaining wall of the structure should be minimum. For a single compartment reservoir of given depth, the most economic shape is given below in order of priority.

- Circular – Most economical
- Ellipse
- Square
- Rectangular
- Shaft type for OHBR

Depth: The depth of the reservoir should always be determined taking site conditions into consideration. Where the depth is very shallow, temperature effects are felt which are likely to affect the portability of water and permit growth of organism. Shallow depths mean larger area and more land cost. At the same time, if the depth is large, this will increase the cost of walls, since these walls have to be thick. The most economical depth is determined by trial. In practice, the depths vary as given in table 8.1.

TABLE 8.1

Capacity	Depth in m
1000 m ³ or less	3.00 – 5.50
> 1000 m ³	6.0 – 9.15

With fixed bottom elevation, the life of pumps increases with increased depth. Also shallow reservoirs give less variable pressure in the distribution system. But too shallow open reservoirs favour high temperatures and increased vegetable growth and hence are disadvantageous.

Reservoir Components

Various components of over head service reservoir are shown in fig.8.1.

Walls: The design of the walls depends upon the size and shape of the reservoir and whether it is open or covered. Small and overhead reservoirs are built circular in form. For covered reservoirs, the design depends partly upon the type of cover used. The wall and joints should be water tight.

Roof: Large reservoirs are usually open. Since roofing is costly. But a roof is preferable to prevent algae growth and to protect against contamination, dust and temperatures changes.

Ventilation: Roofs should have ventilators with wire mesh screen to prevent entry of mosquitoes etc. The height of the vents, in case of a ground level reservoir should prevent entry of frogs, worms etc.,

Inlet Valve: In case of a reservoir fed by gravity, in addition to manually operated Sluice Valve on inlet line, a float controlled inlet valve may be used to close automatically when reaches the designed top water level. Automatic inlet valves should not be used on a reservoir supplied by pumping, as their closing would result in excessive pressure in the rising main resulting in wasteful power consumption.

Outlet Valve: In addition to a sluice valve on the outlet pipe, an automatic closing outlet valves are desirable, when a failure in the outlet main or distribution system causes the velocity of outflow from the reservoir to exceed a predetermined rate. The draw pipe should be placed 15 cm above the floor level to provide a space for sediments to settle down. One extra outlet is desirable for future expansion for joining adjacent reservoir at later stage.

Air Valves: An air valve on the down side of valves is necessary to prevent vacuum in the outlet main

Strainer to Outlet: In case of covered reservoirs there is no possibility of anything entering which may pass down the outlet main and cause obstruction, but there is always a risk of articles accidentally being dropped in, to make recovery of such things possible strainer is fitted to the outlet. It is a fine mesh made of corrosion resistant material and fitted in a manner that will make it possible to remove and wash it frequently

Overflow: This should be of sufficient capacity to take the overflow at the maximum inflow rate. The overflow is useful in cases of failure of the automatic inlet or outlet valve. Generally size of overflow pipe is next larger to the dia of inflow pipe. Disposal of water through overflow pipe should be carefully made keeping in view the natural drainage lines.

Scour pipe: This is to be provided at the bottom of the reservoir with a sluice valve before the T-junction with the overflow pipe. The down pipe should have a gravity chamber at the bottom to prevent entry of debris etc.

Water Level Indicator: Whether reservoir is supplied water by gravity or through pumping, it is essential that water level be known at any desired time and for this purpose, water level indicators are provided. They are operated by floats of different kinds.

Ladder: Ladder to stair case will have to be provided one from the ground level to the roof of the over-head reservoir and one from the inspection chamber of the roof to the floor level of the reservoir to facilitate access for proper maintenance. A helical stair may also be provided. Ladder can be made with flat iron 63 x 10 mm on sides 25 to 30 cm apart 45 cm wide, 20mm dia. Iron ladder are constructed with an angle of 75° (preferred) to vertical at the floor. Ladder shall have minimum 200 mm clearance from any obstruction such as pipes and railing with minimum horizontal clearance of 75 mm from any obstruction such as columns and walls etc., String should be carried one metre above the landing point or roof etc for 75° increased to 1.75m for vertical. If the length of ladder is more than 6m, welded steel mesh cage with minimum clearance of 0.75 m is provided from 2.15m above ground or floor level. Railing should be 0.90 m above ground or floor level. Railing should be 0.90 m to 1.0 m high at landing and hand rail to be from 25 cm for ladder at 600 to 10 cm for 75°, above for the sides of the ladder.

Lighting conductor: It is important to provide an efficient system of lightning conductor to arrest the damage against lightning for overhead reservoirs. The materials used above ground and below ground are shown in table 8.2.

Table 8.2

Materials	Above Ground	Below Ground
Round galvanized wire	No. 4 SWG	No.4 SWG
Galvanized iron strip	20 x 3 mm	32 x 6 mm

8.4. Structural Design of Water Tanks

Clear water reservoirs, settling tanks, aeration tanks etc are supported on the ground directly. Overhead water tanks for water supply may be constructed on masonry walls, steel or concrete staging or on towers. Material used may be steel, concrete, pre-stressed concrete or masonry. From design point of view, tanks may be classified according to their shapes such as rectangular, circular, pyramid, conical, *intz* type and other modern shapes such as spheroids and folded plates. The analysis and design of water tanks proves to be a challenging task particularly when economical design of

unconventional shapes is involved. Reinforced Cement Concrete (RCC) structures are built now a days.

The software available with the department may be used for structural designs

Indian Standard – 3370 code deals with the structures for the storage of liquids.

Part-I	General Requirements
Part-II	Reinforced concrete structures
Part-III	Pre-stressed concrete structures
Part-IV	Design tables

The components such as top dome, cylinder, conical shell and bottom dome have been analyzed individually and designed. Ring beams have been provided at the junction of cylinder top dome, conical shell, and cylinder and bottom dome – conical shell to resist the resulting horizontal forces at the junctions. The moments developing due to continuity effects are taken care of annular raft of required size has been provided as foundation.

The stipulations outlined in the relevant Indian Standards mentioned in the references have been followed in the design. The top dome, top ring beam, cylinder, middle ring beam, conical shell and bottom dome have been designed for uncracked conditions, whereas bottom ring beam, columns, braces and foundation are designed for cracked condition. The container portion is designed with permissible stress concept, whereas the supporting structure is designed on limit State concept.

Specifications & Design Features

Water retaining structures must be built with impermeable walls which will not crack under storage or due to shrinkage and temperature stresses. It should be noted that no amount of over design in steel or concrete can help to overcome the durability problem. For durability, quality of concrete should be aimed at and not quantity. For general guidance, according to **IS-456 -2000** the material used shall be of the following specifications:

- a) **Cement:** The cement shall be ordinary Portland cement or rapid hardening Portland cement conforming to IS-269 or blast furnace slag cement conforming to IS-455. The use of low heat cement is not covered by the provisions of IS-456.
- b) **Aggregates:** All aggregates shall conform to either IS-383 or IS-515. For heavily reinforced concrete members as in case of ribs of main beams, the nominal maximum size of aggregate should usually be restricted to 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum cover to the reinforcement, whichever is smaller.
- c) **Water:** Water used for both mixing and curing shall be free from injurious amounts of deleterious materials. Potable waters are generally considered satisfactory for mixing and curing. Water for concreting and curing should conform to IS: 456:2000
- d) **Reinforcement**
 - a. Mild steel and medium tensile steel bars and hard drawn steel wire shall conform to IS-432 (Part-I)
 - b. Grade Fe 415 conforming to IS 1786-1985
 - c. Deformed bars conforming to IS-1139
 - d. Cold twisted steel bars conforming to IS-1786
 - e. Hard drawn steel wire fabric conforming to IS-1566
 - f. Structural steel sections conforming to IS-226.
 - g. Lap length = 50 x dia of bar

All reinforcement shall be clean and free from loose mill scale, dust, loose rust and coats of paints, oil or other coating which may destroy or reduce the bond. Adhering lime wash or cement grout shall be permitted at the Engineer's discretion so long as it is not excessive or loose.

- e) **Concrete:** In general, the concrete is of seven grades designed as M10, M15, M20, M25, M30, M35 and M40. In designation of concrete mix, the letter 'M' refers to the Mix and the number to the specific 28-day works cube compressive strength of that mix in N/mm².

Strength requirement of materials and other design criteria

- i) When OPC is used, the compressive strength requirement of various grades of concrete and rapid hardening OPC the 28 day compressive strength specified below in table 8.3 shall be met at 7 days.

TABLE 8.3

Grade of concrete	Nominal mix ratio	Compressive strength of 15 cm cube at 28 days after mixing N/mm ² (test minimum)	Quantity of water per 50 kg of cement (Max Litres)
M-10	1:3:6	10	34
M-15	1:2:4	15	32
M-20	1:1½:3	20	30
M-25	1:1:2	25	27

- ii) Allowable stresses in steel: the allowable stresses in steel for water retaining structures are
- Tensile bars in direct tension near the water surface –1000kg/cm²
 - Tensile bars for surface away from water for members less than 22.5 cm thick ---1000kg/cm²
 - Tensile bars for surface away from water for members more than 22.5 cm thick ---1250kg/cm²
 - Compressive stress in columns subject to direct load ----1250kg/cm²
 - Tensile stress for dry materials ----1400kg/cm²
- iii) Allowable stress in concrete

TABLE 8.4

Allowable Stresses (Kg/cm ²)	M-20	M-15
Direct tensile stress	Not more than 12	Not more than 11
	Not more than 17	Not more than 15
	Not more than 17	Not more than 15
	Not more than 70	This is seldom critical

- iv) Minimum Reinforcement (IS-3370 PART II): In walls, floors and roofs in each of the two directions at right angle shall have an area of 0.30 percent of concrete section in that direction for sections upto 100 mm thick. For sections greater than 100 mm and less than 450 mm, the minimum reinforcement in each of the two directions shall be linearly reduced from 0.3% for 100 mm section to 0.2% for 450 mm thick section. For

thicker sections minimum reinforcement is kept at 0.2%. In concrete sections 225 mm thick or greater, two layers of minimum reinforcement shall be placed one near each face of section. The bars used shall be of smallest size practicable. No R.C.C. section shall be of thickness less than $25\text{mm} + 1/40^{\text{th}}$ depth below top water level with a minimum value of 10 cm.

- v) **Minimum Cover:** Minimum cover to all reinforcement is 25mm or the dia of bar if exceeding 25 mm.

Clear cover to reinforcement in conforming to IS:3370 (Part II).

i) All members in contact with water:	25 mm
ii) Top dome and braces	: 25 mm
iii) Columns	: 40 mm
iv) Footings	: 50 mm

- vi) **Flexible Joints:** Special attention shall be given to flexible joints, construction joints, expansion joints and temporary constructions joints.
- vii) **Shrinkage Stresses:** Shrinkage stresses shall be investigated in case of rich concrete mixes and thick walls or in pre-stressed tanks. Co-efficient of shrinkage may be taken as 300×10^{-6} (IS-3370). When shrinkage stresses are allowed, the permissible tensile strength in concrete may be increased by 33.33 per cent.
- viii) **Length of Bond:** The minimum length for bond, or the minimum length of an overlap for liquid containers, keeping in view the permissible stresses of steel comes to 25 d, where d is the dia of bar. For practical purposes, the minimum length of an overlap 30 d, or minimum length 300 mm should be adopted. Hooks at the ends of plain round bars should be invariably provided in liquid containers.
- ix) **Quantity of Water:** The quantity of water required per 50 Kg of cement for various mixes is indicated below. The amount of water is adjusted to give the required workability. The mixture that occupies the least volume, that is the dense, will produce the best concrete. A maximum slump for reinforced concrete is about 150 mm but a stiffer mixture is often desirable and practicable. A slump of 25 mm may be suitable if the reinforcement is not intricate or congested.
- x) **Cube Tests:** Compression tests are made on 150 mm cubes, which should be made, stored, and tested. For cubes made at site, these should be cast from one batch of concrete. Identification marks should be made on cubes. Two sets of three cubes each are preferable and one set should be tested at seven days and other at 28 days. If one set of three cubes is made, they should be tested at twenty eight days. The strengths of cubes in any set should not vary more than 15% of average, unless the lowest strength exceeds the minimum required. The seven days tests are a guide to the rate of hardening; the strength at this age for Portland cement concrete should be not less than two-third of the strength required at twenty eight days.

Permissible stress (Ref: IS: 3370)

a. Concrete (M20 Design Mix):

Allowable stress in bending Compression	:	7.0 N/Sq.mm
Allowable stress in bending tension	:	1.7 N/Sq.mm
Allowable stress in direct compression	:	5.0 N/Sq.mm
Allowable stress in bending tension	:	1.2 N/Sq.mm
Modular ratio	:	13

b. Reinforcement (Fe 415 grade):

Allowable stress in members in contact

In contact with water : 150 N/Sq.mm

- xi) Weight of Materials: The actual weights of materials to be stored in the liquid containing structures should be ascertained
- xii) Floors of Tanks resting on Ground: Estimation of Reservoir structure design of circular – tanks with floors laid on earth).
- xiii) Roof of the Tanks: Under side of the roof of tanks storing chlorinated water get usually corroded due to deteriorating action of free chlorine. Hence such roofs must be in concrete minimum M-25 grade and additional surface treatment for chlorine protection is required to be applied.
- xiv) Safe bearing Capacities of Grounds: The pressure that can be safely imposed on thick strata of soil should be carefully investigated. Table 8.5 gives some pressures which are often recommended as a guide, but this pressure must be considered as maximum since there are several factors that may necessitate the use of lower values. Further the tabulated pressures are for dry materials. Assume 50% if the soil is saturated.

TABLE 8.5

Type of ground	Silt, Alluvial earth	Soft clay	Loose sand	Gravel	Rock soft	Hard rock
SBC T/Sqm	0-8	< 8	11-22	22-44	16	32-64

- xv) Wind Pressure: Since the primary factor in the design of isolated structure is the force of wind, careful consideration is necessary to avoid either under-estimating this force or making an unduly high assessment. Due account should be taken of the susceptibility of narrow shafts to the impact of gust of winds. The total lateral force is the product of specified pressure and the maximum vertical projected area and a factor of safety of at least 1 ½ is required against overturning. Local meteorological records should be consulted to determine maximum wind velocity.

IS- 875, Code of Practice for structural safety of buildings: Loading Standards. provides the figures of maximum basic wind pressure ever likely to occur in respective areas including winds of short duration, meaning thereby winds in which the maximum speed is attained suddenly and lasts for a few minutes only such as in squalls.

The distribution and intensity of the resultant pressures due to wind depend upon the shape of the surface upon which the wind impinges.

Wind velocity and pressure at various exposed heights

TABLE 8.6

Height of exposed surface above mean retarding surface (m)	Horizontal wind velocity (km/hr)	Horizontal pressure (kg/cm ²)
0	80	40
3	96	58
6	108	73
9	115	85
12	123	98
15	128	105
18	133	112
21	137	120
24	141	127
27	144	133
30	147	141
38	155	151
Height of exposed surface above mean retarding surface (m)	Horizontal wind velocity (km/hr)	Horizontal pressure (kg/cm ²)
46	160	166
53	165	175
61	169	185
76	175	200
92	181	210
107	186	224
122	191	234

Economical Foundation of Soils with Low Bearing Capacity

The site for the construction of service reservoir is selected as near as possible to the centre of the zone, at the highest contour and at a point where there is availability of sufficient space. While satisfying these conditions, it happens at times that the service reservoir has to be located at a site with a low bearing capacity due to non-availability of other suitable sites.

In such cases there are two alternatives to tackle the problem

- Adopting suitable methods by which we can increase the bearing capacity of the soil to a desired level and propose the usual type of foundation.
- Adopting suitable foundation conforming to available bearing capacity of the soil.

Improving Bearing capacity by compaction

When soft soils are encountered, the deposits may be removed and replaced by compacted fill. Some of the common methods of compaction are:

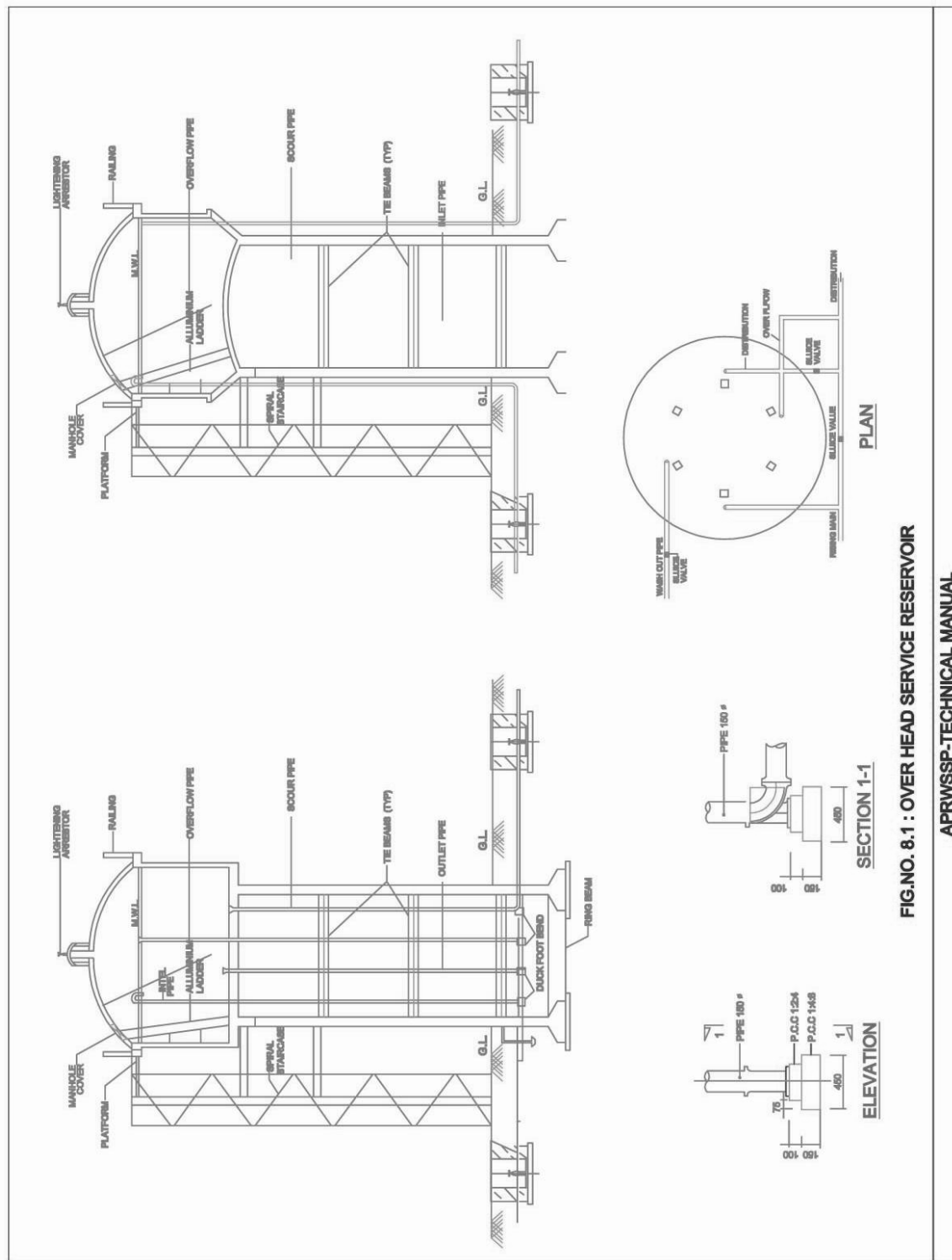
- Flooding: Only very loose sand can be affected by flooding with water. The degree of compaction is very little.
- Vibration: Heavy vibratory rollers and compactors may compact a layer of granular soils to a depth of several feet.
- Vibro-floating: A commercial method which combines the effect of vibration and jetting. A heavy cylinder known as vibrofloat, is inserted in the ground while the cylinder vibrates due to rotary concentric weight, a water jet on the tip of the vibrofloat supplies a

large amount of water under pressure. As the vibrofloat skins, clean sand is added into a creator that envelops on the surface.

- d) Sand Drains: To accelerate consolidation process, vertical sand drains may be installed at uniform spacing. Holes of 300 mm or greater diameter are bored and filled with clean sand. The top of these drains are interconnected by sand trenches or blanket.

Compaction of earth fill is accomplished by spreading fill materials at moisture near the optimum water content. If the soil taken from barrow pits is too dry, additional water can be provided by sprinkling and mixing each layer. The thickness of each layer is 150mm. Common types of compaction equipment are: (1) Smooth faced steel roller (2) Pneumatic tired roller, (3) Sheep foot roller, (4) Lyrical roller (5) Segmental wheel roller (6) Mechanical tamper (7) vibrating tamper (8) Earth moving equipment.

However various methods of improving bearing capacity have their own limitations. For very heavy structures, sand filling etc will result in lateral movement of soil and consequent undesirable settlement. So these can be adopted only for service reservoirs of small capacity say upto 10 lac litres. For heavy structures only pile foundation will be economical when soils of low bearing capacity are encountered.



CHAPTER-9

9. DISTRIBUTION SYSTEM

The purpose of distribution system is to convey wholesome water to the consumer at adequate residual pressure in sufficient quantity at convenient points. The requirements for the distribution systems are network of pipes connected to reservoirs with valves at suitable locations for efficient operation and maintenance. Adequate residual pressure at maximum demand depending upon the hydraulic capacity of the system should be provided. Normally, water supply is intermittent in a rural water distribution system. Usually water supply is made twice a day at the rate of 4 hours each time, which is equal to 8 hours per day.

In rural water supply schemes 8 hours distribution of water is being provided and hence a peak factor of 3 is to be considered for design of distribution lines. The road network pattern in a village is normally with dead ends and rarely the roads are connected. Though ideally a grid network is desirable, in a rural water supply system, dead end pipe systems are common. In a dead end system, a single trunk main takes off from the OHSR with smaller mains branching off from the trunk main.

A single trunk main may be sufficient where elevation difference between highest and lowest point in the village is not more than 10m. when the difference in elevations is more than 10m, two trunk mains taking off from the outlet main at OHSR may be required, one to serve the high level areas and the other to serve the low level areas. Wherever, it is possible the distribution system of the high level and the low level may be interconnected to provide emergency supplies. However, the interconnection valves between the zones shall normally be kept closed.

There are indeed so many points that must be considered in laying out distribution systems, that each case must, to a certain extent, be taken upon its own merits. Generally a grid pattern system interconnecting different mains and keeping dead ends to bare minimum is preferred.

9.1. Zoning

In order to equalize the distribution of water throughout the area, zoning is necessary in the distribution system. In the area under consideration zoning, sometimes there are trade and manufacturing zones and the central portion of the city where there are large and lofty shops and public buildings. Voluminous supplies are necessary for trade purposes, including hydraulic lifts, large tanks for feeding boilers, breweries, laundries, aerated water manufacturers and many other purposes, besides there being the necessity for immense volume of water at fire hydrants in case of extensive fire breaks out.

The residential zones, however, require pipes of ample size, as they are liable to very heavy drawn for street washings as well as domestic supplies. The residential zones vary much in character, some parts being densely populated with small tenements closely packed together, where the drawn is very heavy, while other portions have far fewer houses to a given area, yet in the latter case the residences will often be large and costly, requiring a very ample supply of water and every provision in case of fire.

9.2. General design parameters for distribution system

Peak Factor: The distribution system should be so designed that its capacity is adequate enough to meet the maximum hourly flow which can be calculated by multiplying the average flow with the peak factor. The CPHEEO Manual recommends the peak factor as 3 for rural water supply schemes with population less than 50,000 (Where water supply is affected through stand posts for only 6 hours)

Pressure requirements: The following minimum residual pressures should be available in the distribution system as per recommendations of the CPHEEO Manual.

Single storey building (Direct Supply)	-----	7m
Two storey building	-----	12m
Three storey building	-----	17m

The distribution system should not ordinarily designed for residual pressure exceeding 22m. Boosting arrangements should be made for high rise buildings requiring higher pressure.

Capacity (Minimum pipe sizes): The distribution system should be capable of providing fire fighting demand as a coincident draft along with normal supply of water to the consumers. Minimum size of 100mm dia pipes for villages having population upto 50,000 and 150 mm pipes for those above 50,000 and for dead ends less than 100 mm can be considered. In case of grid where no further expansion is contemplated, less than 100 mm pipe size can be used.

Layout of distribution system-zones: In laying out a distribution system, very important question is of level and it is necessary to carefully consider these in planning out the system. In those parts of zones which are on a comparative level, the more the mains are in circulation having regard to avoidance of undue complication, the better will be the supply, but where the levels vary considerably, if it were not for the excessive cost, it would be desirable to lay a separate set of leading mains to each range of levels.

The zoning depends upon the density of population, type of locality and topography etc. When there is an average difference in elevation 15 m to 25m between zones then each zone should be served by a separate system. The valves between zones should be kept closed and used only under emergent situations. The layout should be such that the difference in pressure between different area of the same zone or same system does not exceed 3 to 5 m. This would, however, in many cases necessitate the laying of great lengths of extra mains, as the second lot of pipes would have to run through many areas to reach the higher levels beyond.

The groups of distribution pipes to varying levels should, however, be kept as separate as possible. But when the higher levels are adjacent to the reservoir from which the leading mains originate, the pipes should have larger dia at starting, and until they have passed through, and supplied the higher parts, they should then be reduced in dia as they continue towards the lower levels. By carefully arranging the sizes of the pipes with regard to the question of levels, the evil of low lying injuriously affecting the supply in the higher parts may be minimised

- a) Survey and Map: The pre-requisite to sound design of distribution system is a complete survey covering all streets and indicating elevations of all important point proposed as well as present streets. The plan of the villages can be shaded to show density of population and anticipated number of persons per acre should be indicated.

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- b) Location of Reservoirs in different Zones: As already discussed where the levels vary considerably, it would be desirable to lay a separate set of leading main to each range of levels.
 - c) Distribution system: Depending upon the area of high level and low level zones to be served from high level and low level reservoirs, the population will be worked and requirement of water for each zone arrived at. Supposing total population served is 60,000, it is assumed that $\frac{2}{3}$ rd of the population can be served from low level reservoir and remaining $\frac{1}{3}$ rd from high level reservoir.

9.3. Types of Distribution Systems

The various types of distribution system are

- a) **Grid area system**: This system eliminates the dead ends and thus permits circulation of water. In case of heavy draft on leading mains or branch lines, the system permits drawing of water from other connected mains. By locating the valves properly, in case of repair of one pipe the area from which water is cut off can be reduced to one block only, keeping the supply in rest of the area uninterrupted. Valves are generally installed three at crosses, two at T-ees, and one on single hydrant branch.
The only disadvantages in this method are that the distributing mains are rather more complicated and more turn-off valves are necessary and the labour in turning off various sections in the sub-districts is slightly greater.
- b) **Dead-End System**: As the name implies this is a system in which the main line is laid on the main road, from these, smaller pipes serve individual streets but do not connect at their ends with other mains. In this system if a pipe line near the centre of the system develops fault, a large area will be without water.
- c) **Compromise System**: In most of the cases, only compromise system is possible. In this system the pipes provide circulation only where it is provided at reasonable costs, but where it is not feasible to connect the pipe ends they are left unconnected and adequate arrangement for flushing through hydrants is made. The examples of such cases are that it is costly to lay a pipe line across a rocky bed of the stream or under a rail road multiple track or a multilane highway etc. Under such situation, dead ends are unavoidable.

In RWS&S department grid area system is being followed

9.4. Methods of Network Analysis

The network analysis method in the design of water distribution system consists of sizes of pipes, sizing of reservoirs and fixing the location of reservoirs and pumps etc suitable for the proposed layout. The modified Hazen-William's formula is popularly used for finding out the size of the pipe for a given flow.

- 1) Trial and Error Method: In this method the heads or flows are assumed in the pipe system and the corresponding heads and flows obtained by the use of tables in CPHEEO Manual, based on modified Hazen-William's formula, the nearness of assumed head or flows is tested. The process is repeated till the time the head losses and flows agree within 0.3 m and 2% respectively when a correct solution is found.

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- 2) Computation in Dead End System: The design of dead end distribution system is done taking into consideration of present & prospective population, topographical map of the town and the layout of the piping etc.
 - 3) Hardy Cross Method (Balancing Heads): The methods discussed above can be employed to any distribution system. The problem becomes more complex when there are series of interconnected endless line in the layout of the system. For such systems, a method developed by Professor Hardy Cross is most widely used. The Hardy Cross method is a controlled trial and error process in which the heads are balanced. In layout of a system like grid iron, water travels and reaches different points by more than one route. It is, therefore, necessary first of all, to find out the quantities of flow passing via each route.

9.5. Hydraulic Network Analysis

A pipe network map corresponding to the road network of the village is prepared for hydraulic analysis. The total length of present pipe network is calculated. The estimated population/households for the design period are arrived at. From this data the households per running meter of network is calculated and hence the demand per running meter of the pipe network is calculated. The demand for each pipe section is arrived calculating from the end point as per the number of the households per running meter. The cumulative demand is calculated for each branch and for the trunk main. This demand is average demand; however, the network is to be designed for the peak flow. The pipe network is then analyzed for the estimated demand using the suitable peak factor.

Input data

In the Hydraulic network design one of the important criteria is the head loss allowed in the distribution system. This is also an important constraint required in the optimization of pipe sizes required in the linear programming model. The use of smaller diameter pipes results in higher head loss which calls for higher staging heights of OHSR to ensure desired residual pressure at the farthest delivery point. On the other hand, use of higher diameter pipes results in lower head losses but increase the cost of the pipeline. Hence the pipe sizes selected shall be optimized using the maximum and minimum head loss that can be permitted. Usually a minimum head loss of 0.1 – 0.5 m/km and maximum head loss of 5-10 m/km are adopted in a rural water supply system.

The minimum head loss is calculated as the drop in elevation from the LWL of the OHSR to the lowest point in the village divided by the distance from the OHSR to the lowest elevation point along the network. The maximum head loss is calculated as the drop in elevation from the MWL of the OHSR to the highest point in the village divided by the distance from the OHSR to the highest elevation point along the network.

Next important input to the analysis is the Hazen – William's coefficient 'C' for design purpose is to be given as input based on the type of pipe material used in the network. The design value of 'C' for GI pipes is 100 and the design value of 'C' for PVC/HDPE pipes is 145.

The diameters in a rural water supply distribution system vary from a minimum of 50mm to a maximum of 200mm, which make about 9 different pipes of commercial diameter available for use. The distribution system will be designed for a peak factor of 3 with a minimum residual pressure of 8 meters.

Software programs are available for solving the dead end network and loop system for rural water supply system. The output diameters may given at some points residual head of more than 8 meters. This may be due to the low ground levels at the point. In such case, the particular diameter of the

branch is further reduced and another analysis is carried out to verify the residual head. Sometimes the diameter of that particular branch may be a minimum diameter which cannot be further reduced. In such case the diameter of pipe in the main line just prior to the branch or the diameter of the pipe at the starting point of the OHSR is to be reduced and another analysis carried out. This kind of trial and error procedure is carried out till residual head at all the points of the network is more or less near to 8 meters.

9.6. Location of the valves

One sluice valve shall be located at the starting point of the distribution system near the OHSR to cutoff or restore the flow from OHSR into the distribution system. Each branch is also provided with one sluice valve for controlling the flow into that branch. Valves on the main line are not recommended. However, main line valves may be installed where it is necessary to isolate the supply of water to the various zones. The need for Scouring a distribution system arises rarely. However, in an intermittent supply, water stagnates in valley portions, which has to be drained out so that stagnant water is not supplied to the consumers. Hence scour valves are provided in the valley portions. The size of scour valve in a distribution system of rural water supply shall not normally exceed 50mm. Further this valve must be protected against misuse and provided with a masonry chamber and a cover with a locking arrangement. The outlet of scour valve shall be connected to a drain. It should be ensured that wastewater from the drain will not contaminate the drinking water through the scour pipe. All drain crossings of the distribution system pipes shall be provided with an outer casing pipe to prevent contamination by the drain water. A typical sketch showing location of air valve and scour valve in distribution system are shown in fig.9.1.

9.7. House Service Connections

The supply from the main pipeline to the individual houses is made through a house service connection. For a house service connection, ferrule is used on the main line either to control the flow or for permanent disconnection. The ferrule is sufficiently throttled to deliver required flow at the contemplated pressure. The size of the ferrule shall not be more than $\frac{1}{4}$ of nominal diameter of the main pipe and also be less than the diameter of the connecting pipe. In case the main pipe is of PVC, special screwed saddles are fixed on to the pipe. Sometimes the connecting pipe to the consumer house may pass through a drain then there is a possibility of the contamination with drain water through any leakage in the consumer pipe. If the consumer pipe is with GI, it may corrode over a period of time when exposed in the drain portion, which may cause similar contamination. Hence it is recommended that the casing pipe be provided around the consumer pipe when drain is to be crossed. A typical house hold service connection is shown in fig.9.2.

Public Stand Posts

Typical construction details of public fountain/ Stand Post are shown in Fig. 9.3 & 9.4

9.8. Distribution of Water and water meters

Water shall be transferred to OHSR by installing bulk meters conforming to IS: 2373-1981 (third revision) at inlet point in a village. Individual house connections shall be given through ferrules conforming to IS: 2692-1978 and domestic water meters conforming to IS: 779-1978 (Fifth revision) shall be installed at consumer end

Purpose of Water Meter

- i) It is an integral part of a house service connection.
- ii) The water meter fixed should conform to IS 779 – 1978
- iii) It is used to measure the quantity of water consumed by the House hold.

The minimum distance between water meter and any pipe line special should be 2.75D on both sides. Similarly for strainer also the minimum straight distance should be 2.75D so as to maintain laminar flow.

For measuring the water distributed to the community it is suggested to provide water meters conforming to ISO 4064 (International Standard).

The water meter should satisfy the following minimum specifications.

- 1) It should be of Bulk type/Woltman Model with removable mechanism
- 2) The same should be suitable for Metric registration
- 3) The meter should withstand for a working pressure of 16 Kg/cm²
- 4) End connection: Flanged and drilled as per BS 4505
- 5) Painting Epoxy powder coating
- 6) Bearing jewelled Rotor bearing

Guidelines for Selection, Installation & Maintenance of Domestic Water Meters

IS 779 – 1978 covers the selection, installation and maintenance of inferential and semi positive water meters. Water Meter should be selected based on discharge only Water meters shall be selected according to flow to be measured and not necessarily to suit a certain size of main as shown in table 9.1.

TABLE 9.1

Meter size (mm)	50	80	100	150
Max flow (m ³ /hr) ± 2%	30	80	120	300
Continuous flow (m ³ /hr) ± 2%	15	40	60	150
Minimum flow (m ³ /hr) ± 2%	0.45	1.2	1.8	4.65

The following points shall govern the selection of meters:

- a) The maximum flow shall not exceed the nominal capacity of the meter specified in IS 779-1968*.
- b) The continuous flow shall not be greater than the continuous running capacity rating specified in IS 779-1968*.
- c) The minimum flow to be measured shall be within minimum starting flows specified in IS 779-1968.

Inferential water meter has the same accuracy as the semi-positive type at higher flows. It passes unfiltered water better than a semi-positive meter and is lower in cost.

Special care is necessary in selecting the most suitable meter where large rates of flow may exist for short periods. The normal working flow shall be well within the continuous running capacity specified in IS 779-1968. As high rates of flow over short period may cause excessive wear if the meter chosen is too small for the duty.

Owing to the fine clearances in the working parts of meters, they are not suitable for measuring water containing sand or similar foreign matter, and in such cases a filter or dirt box of adequate effective

areas shall be fitted on the upstream side of the meter. It should be noted that the normal strainer fitted inside a meter is not a filter and does not prevent the entry of small particles, such as sand.

- Installation: A meter shall not be run with free discharge to atmosphere, if the static pressure on the main exceeds 10m head of water, otherwise the meter is liable to be overloaded and damaged. For house connections and similar applications, there shall always be some resistance on the downstream side of the meter.

A Meter shall be located where it is not liable to get severe shock of water hammer, which might break the piston or damage the rotor, and the position shall be such that it is always full of water. If the meter body or adjacent pipes become partially drained of water, the accumulated air, when passed through the meter, is registered as water, and may cause inaccuracies and perhaps damage. The inaccuracies may be more pronounced in the case of inferential meters. In such situations suitable devices like air-release valve may be fitted on the upstream side of the meter. In the case of intermittent water supply system, where there are frequent changes of air locks, the piston of the semi-positive meter often breaks. In such a case, it is advisable to ensure that the top of the meter is below the level of the communication pipe.

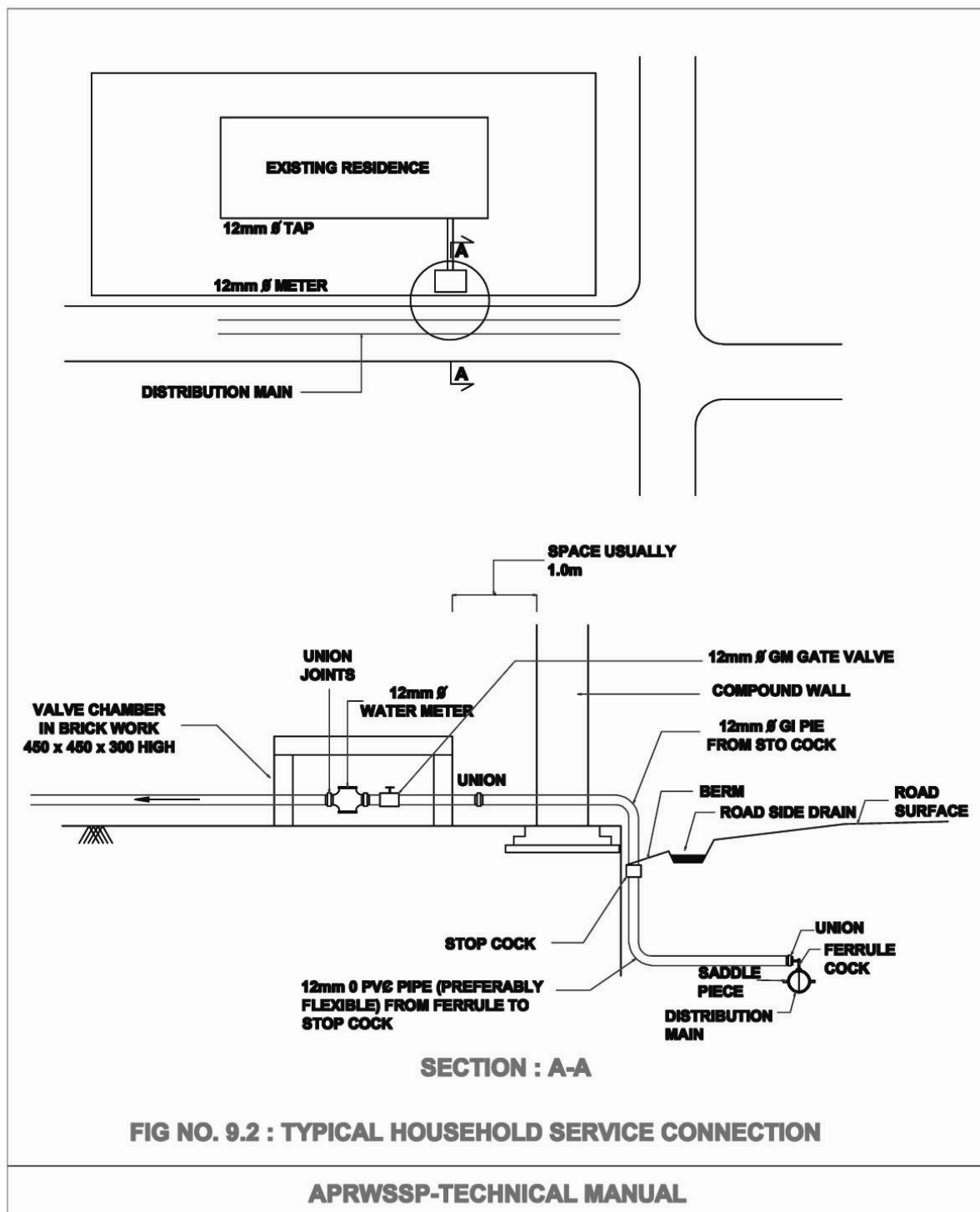
Semi-positive meters may be fixed in any position, with the dials facing upwards or sideways, and they may be installed in horizontal or vertical pipe runs without affecting wearing properties of accuracy at normal service flows. Where backward flows are anticipated, reflux valves are recommended to be provided. A stop valve should be provided on the upstream side to isolate the meter whenever necessary.

Inferential meters shall be installed in position for which they are designed in the case of meters conforming to IS 779-1968. They shall be placed horizontally with dial facing upwards. However, where meters are to be installed in vertical pipelines, details shall be as agreed to between the manufacturer and the purchaser.

Turbulent flow of water affects the accuracy of the meter. There shall, therefore, be straight lengths of pipes upstream and downstream of meter for an equivalent length of ten times the nominal diameter of the pipe.

Meters liable to damage by frost shall be suitably protected. It is possible to incorporate frost protection devices in certain types of meters, if ordered. Several devices are adopted, the most common among them being a collapsible metal ring which, under frost pressure, allows the top plate carrying the mechanism to lift and thus safeguard the body, or a metal disc in the body which gives way under pressured. These devices have the following disadvantages.

- a) The damaged ring or plate requires immediate replacement in order to stop wastage and restore water supply to consumer.
- b) Water runs to waste till the meter is attended to which means loss of revenue and
- c) Damage is discovered only after thawing has started.



CHAPTER – 10

10. RURAL SANITATION

10.1. Sanitary Works

Sanitary engineering starts at the point where water supply engineering ends. All the taps, fixtures and appurtenances that receive water for use, discharge into the waste-water systems. Sanitary engineering starts with the collecting system and ends after the streams or other bodies of receiving water have been returned to the condition of relative purity desired for them. The sanitary works can be broadly classified as:

- i) Collection works,
- ii) Treatment works, and
- iii) Disposal works

Collection Works

The collection works are mainly meant for collecting all the types of waste products of the village. Refuse is collected separately and the sewage is collected separately. The collection works should be such that waste matters can be transported quickly and steadily to the treatment works. The system employed should be self-cleaning, hydraulically tight and economical so that even poor authorities may afford it.

The collection works include the house drainage works network of sewers laid in the village to collect the waste water from individual houses, public places and industries, the drainage system should not allow the disease bacteria and foul gases to escape into the atmosphere inside the buildings and crowded localities. Disease bacteria and mosquitoes may breed at the catch basins and other sewer appurtenances; therefore they should be designed in such a way as to avoid these troubles.

Treatment Works

Waste water treatment works are required to treat the sewage before disposal so that it may not pollute the atmosphere and the body of water in which it will be disposed of. The types of treatment processes depend on the nature of the hygienic, aesthetic and the economical aspects. If the waste water is not treated it will do much harm, few of which are:

- i) pollution of water supplies for human and industries
- ii) destruction of food, fish and other valuable aquatic life
- iii) contamination of bathing places, and ice supplies
- iv) creation of unpleasing sights and atmosphere pollution of air
- v) Contamination of water and making it unfit for any purpose such as commerce, recreation or other important works

In hilly areas or some other places where conditions permit, the treatment works can be avoided and the water can be directly disposed of in natural water courses. While designing the treatment process, they should be designed in such a way that treated water becomes so pure that it can be used for general purposes although it may not be used.

Disposal Works

The treated or untreated waste waters are disposed off in various ways by irrigating fields or discharging into natural water courses.

10.2. Aim and Objectives of Sewage-disposal

The following are the aims and objects of sewage disposal

- i) Proper disposal of human excreta to a safe place, before it starts decomposition and may cause unsanitary conditions in the locality.
- ii) To take out all kinds of waste water from the locality, immediately after its use, so that mosquitoes, flies, bacteria etc., may not breed in it and cause nuisance.
- iii) Final disposal of sewage on land or in nearby water-courses after some treatment so that receiving land or water may not get polluted and unsafe for its further use.
- iv) As far as possible the fertilizing elements of sewage may be used in growing crops through sewage farming and getting some income in addition to the disposal of sewage.
- v) In unsewered areas, the treatment of sewage from individual houses should be done by septic tank or other suitable means, and the effluent should be disposed of.
- vi) If the sewage is disposed of on the land, it should have such a degree of treatment that it may not affect the sub-soil in any way.

Provision of adequate sanitation facilities in the form of safe disposal of sullage and human excreta from the residential houses is one of the essential requirements of environmental sanitation. In addition, proper collection and disposal of solid waste generated is of prime importance to minimise environmental pollution. Traditionally in the rural areas, people are used to defecate in open areas due to lack of household toilets.

10.3. Low Cost Sanitation

A high priority is given to low cost sanitation in villages where regular sewerage is not contemplated. Since excreta are the cause of more than 50 diseases, immediate concern of any programme of environmental sanitation in India has to be the replacement of dry latrines with sanitary ones.

Twin Pit Pour Flush Latrine (TPPFL)

Twin pit pour flush toilets to the rural communities, since these toilets require less water and also do not pollute the ground water table. Further these toilets are economical and easy to construct and maintain. The government of Andhra Pradesh provides subsidy for construction of toilets for families of BPL and APL. A schematic diagrams of twin pit pour flush type toilets are shown in fig.10.1 and 10.2.

TPPFL consists of a squatting pan, a trap with water seal, footrests, a connecting drain and two leach pits. The principle is that small quantity of water is used for flushing the toilet so that water leaches easily into the surrounding soil and leaving the solids alone for digestion.

The squatting pan is of special design with steep bottom slope of 25° -28° with a trap having 20cm water seal set on a cement concrete floor. The slope of the toilet pan is such that pouring small quantity of water (about 1.5 to 2 litres of water per use) can flush human excreta.

The squatting pan is connected to twin leach pits through a trap and a pipe or covered drain. The flushed contents from the squatting pan flows and fills the connected leach pit. When one pit is full, the excreta is directed to the second pit. The filled up pit can be conveniently emptied after 1 1/2 to 2 years. When most of the pathogens die off, the sludge can be safely used as manure. Thus the two pits can be used alternately and continuously.

Pour-flush water seal latrine is a very satisfactory and hygienic sanitation system and hence it can be located even inside the house yards since the water seal prevents odour and insect nuisance.

TPPFL pits in water Logged, Flood prone and High Sub-soil Water Areas

In high sub-soil, water logged or flood prone areas; the pits should be raised above the ground level to a height such that the invert of the incoming drains/pipes is just before the likely floodwater or sub-soil water level. Raising the pipes will necessitate raising the latrine floor also.

In pits located in water logged or flood prone areas, earth should be filled and well compacted all around the pits in 1000 mm width and up to the top. It is not necessary to raise the pits by more than 300 mm above the plinth of the house because if water rises above the plinth, the residents will anyway vacate the house.

In high sub-soil water areas, about 300 mm filling all around the pits may be done depending on site conditions.

In these situations, the pits should be designed as wet pits, taking into consideration the infiltration rate of the type of soil.

TPPFL pits in Rocky Strata

In rocky strata with soil layers in between, leach pits are designed on the same principles as those for low sub-soil water level taking the long term infiltration capacity of the soil as 20 litres per sq.m per day. However, in rocks with fissures, chalk formation, or old root channels, pollution can flow over a very long distance; hence these conditions demand careful investigation and adoption of pollution safeguards.

Since there will be no infiltration of liquid in impervious rocky strata, the pits will function as holding tanks. In such situations, a PF latrine with leaching pits is not a suitable system.

Leaching capacity tends to be the limiting factor when the infiltration capacity of soil is low. In these circumstances, there are two options; construct a larger pit, or increase the critical leaching area. The former option is costly, while the latter can be accomplished by backfilling and compacting with brick ballast, gravel, sand etc., in the required width all around the pit, since the leaching area is the vertical surface of the excavation of the pit rather than the external wall of the pit.

Pits in black cotton soil are designed on the basis of whether the pit is wet or dry, taking the infiltration rate as 10liters per sq. meter per day. However, a minimum 300mm vertical fill (envelop all around the pit) of sand, gravel or ballast of small sizes should be provided all round the pit, outside the pit lining, to separate the soil and the pit lining as well as to increase the infiltrative surface area.

Design of Pan

Based on the design developed in India and abroad, the pour flush latrine with twin leach pits (one to be used at one time) adopted by the project consists of a Squatting pan of special design, having a steep gradient at the bottom and of particular depth only along with a trap having 20 mm water seal. The human excreta can be flushed by pouring 1.5 to 2.0 litres of water in the pan. The flushing reach one of the twin leach pits constructed in the house compound or where this is not possible, under the foot path or under the road. The squatting pan and trap unit can be of ceramic or glass fibre reinforced plastic (GR) or HDPE or PVC and is connected with the leaching pit through a pipe or covered drain.

The minimum size of the latrine should be 750 x 900 mm as per UNDP design while the preferable size should be 800 x 1000 mm. the length of each foot rest should be 250 mm and width 120 mm. Foot rests should be 25 mm above the floor level.

Leach Pit

The pits are lined with honey comb brick work, open jointed stone, or with perforated burnt clay or concrete rings. The pits are circular and used alternatively and designed for 3 years filling period. When one is filled it is stopped, the excreta being diverted to second pit. The content becomes rich organic humus, innocuous and free from pathogens as well as smell. When convenient, it is emptied and contents used as organic manure.

Size of Leach Pits: The size of leach pits depends upon a number of factors such as soil characteristics, sub soil water level, interval of cleaning, number of users etc., the effective volume under dry conditions should be at least 0.135 m^3 per capita of the household for a period of 3 years. In case ground water rises above the bottom of the pit during any time of the year, the pit capacity should be increased.

Shape of the Pits: Leach pit configuration can be varied to suit site conditions while the least cost design is a twin circular pit.

Soak pit

Soak pits are used to dispose the effluents of the drain into ground where drained cannot discharge the effluents in a natural stream. These are ideally suitable for the regions where the terrain is flat and no nala is available near the village. Normally, soak pits are provided next to stand posts, hand pumps and washing platforms so that wastewater does not get accumulated in the vicinity.

In general, the disposal of effluent may be either underground or over ground. Normally, underground disposal either in the form of soak pits or dispersion trenches is practiced. Satisfactory disposal depends on porosity and percolation characteristics of the soil.

When black cotton soil is encountered, conduct percolation field test on the soil near the proposed disposal site. Normally, permeability value for the black cotton soil will be very less. This value has to be taken for designing the disposal system. Most of the time it is desirable to adopt a battery of dispersion trenches depending on the rate of percolation obtained from the field test and providing larger length of dispersion trenches.

To arrive at the size of the soak pit depending upon the soil conditions for a known effluent quantity is as follow:

The important parameter to be determined is the rate of percolation of filter media. This is most important in clayey soils, which are relatively impervious. For this, the following procedure shall be adopted.

Drill a hole of dia 300 mm to the required depth of soak-pit/dispersion trench at the site chosen for constructing the soak pit. Remove all loose materials from the hole and fill up coarse sand or fine gravel to 50 mm depth to prevent scouring of the bottom. Fill up water to a depth of 300 mm in the hole and allow 24 hours, so that soil gets saturated with water by pouring water on subsequent days till some water remains in the tested hole after the overnight swelling period. Now top up the water to get a depth of 150 mm of water over the sand in the hole. Now the hole is ready for carrying the test.

From a fixed reference point, measure the drop in water at 30 min intervals for 4 hrs. If necessary, water can be refilled to 150 mm depth over the gravel. The drop in water level that occurs during the final 30 min period shall be used to calculate the percolation rate.

Note: In case of sandy soils, water seeps away in less than 30 minutes. Hence, the time interval between measurements may be taken as 10 minutes and the test run for 1 hr. The drop that occurs during the final 10 minutes shall be used to calculate the percolation rate.

Calculation of Percolation Rate

Based on the final drop during the period of 30 minutes (for sandy soils 10 minutes) the time in minutes required for water to fall by 25 mm shall be calculated, which is the percolation rate.

Technical Aspects

For an average condition, 0.8 m distance between leach pit and house foundation is enough. Since the objectives of the project is to cover each and every household with latrines, 9 type designs for possible alternatives for Indian conditions are developed, for household with 5 persons, 10 persons and 15 persons and with leach pits feasible.

Standardization

Pan and trap are important components of low cost pour flush latrines. Low cost Glass PVC/GRP Pans have been designed by TAG (India). Standardisation is necessary so that different manufacturers can produce uniform quality. Draft specifications prepared by TAG (India) were finalised by ISI in consultation with National Building Organisation.

Sanitation Facilities for Slum and Rural Areas

A slum is predominantly a residential area where dwellings are detrimental to safety of health by reasons of dilapidation, over-crowding, faulty arrangements of design, lack of ventilation, sanitary facilities or any combination of these factors.

In India about one-fifth of population habitat lives in slums. Mostly slum dwellers are labourers employed in small works. Susceptibility to disease is much higher in these areas mainly because of poor environmental conditions resulting in higher morbidity and health rates.

Any scheme for slum and village improvement should include the facility of sanitary latrines, proper and sufficient space for bathing and washing, arrangement of safe water supply for drinking and domestic purposes and proper drainage facilities.

Use of locally available material for household toilets and drains

In order to economise the construction of the household toilets and drains it is necessary to prepare the plans and estimates using locally available material such as bricks and stones for construction of toilets, stone slabs for lining of drains, etc., to the maximum possible extent. Locally available artisans, masons, plumbers, unskilled workers could be deployed for work, and certain factory made materials such as CI pipes, PVC pipes, FRP/ceramic water closet can be procured.

10.4. Water Pollution Aspects and Pollution Safeguards

Extensive water pollution studies conducted in India and elsewhere have confirmed that:

- (a) There is no risk of bacterial pollution when the pit is in alluvial soils with predominance of silt mixed with clay and fine sand if the pit bottom is at least 2 m above the maximum water level.
- (b) Even under unfavourable conditions such as coarse sand, high water table and where the soil depth beneath the water table is less than 2 m, this twin leach pit pour flush latrine system can be used with one or more of the following modification as necessary.
 - (i) Providing an all round minimum 500 mm thick envelope of fine sand of average size 0.6mm sieve.
 - (ii) Sealing the bottom of the pit by any improvising material such as puddle clay or any polythene sheet.
 - (iii) Keeping the inlet of the pit at least 1 m above the maximum ground water level in high water table conditions.

Pollution Safeguards

Proper information and investigation of geological/hydro geological conditions of sites where pits are to be located, and the location of drinking water sources, size, all are pre-requisites in planning, designing and construction of on-site low cost sanitation systems to ensure that pollution risk to ground water and water distribution mains is minimal. faulty construction and wrong data/information regarding hydro geological conditions may lead to pollution of drinking water sources.

To ensure that the risk of polluting ground water and drinking water sources is minimal, the following safeguards should be taken while locating the pits:

- a. Drinking water should be obtained from another source or from the same aquifer but at a point beyond the reach of any faecal pollution from the leach pits.
- b. If the soil is fine (effective size 0.2mm or less), the pits can be located at a minimum distance of 3m from the drinking water sources, provided the maximum ground water level throughout the year is 2m or more below the pit bottom (low water table). If the water table is higher, i.e., less than 2m below the pit bottom, the safe distance should be increased to 10m.
- c. If the soil is coarse (effective size more than 0.2mm), the same safe distance as specified above can be maintained by providing a 500mm thick sand envelope, of fine sand of 0.2mm effective size, all around the pit, and sealing the bottom of the pit with an impervious material such as puddle clay, a plastic sheet, lean cement concrete, or cement stabilised soil.
- d. If the pits are located under a footpath or a road, or if a water supply main is within a distance of 3m from the pits, the invert of the pipes or drains connecting the leach pits should be kept below the level of the water main, or 1m below the ground level. If this is not possible due to site considerations, the joints of the water should be encased in concrete.

Diversion of Flow from One Pit to another

Only one of the two pits is to be used at a time. It is very important to completely seal the entry to the pit that is not in use. This is done by blocking one of the junction chambers. When water does not flow out of the pan, either there is chockage or the pit in use is full. If by rotting, the chockage is not removed, then the pit in use is full and the flow needs to be diverted to the second pit. For this, remove the pit not in use and block the flow to the pit that is full. Cover the drain or the junction chamber properly so that foul smell is not emitted.

Removal and Disposal of Pit Sludge

When the filled pit is allowed to rest for a minimum of 1 1/2 year, the pit contents are completely digested and free of foul smell. The pit can then be safely emptied manually, without being hazardous to health, by the householder himself or through the local authority or a private agency. However, in the case of combined pits and pits located in water logged and high sub-soil water areas, de-sledging of pits should be done carefully because the sludge might not be completely safe and dry to handle due to travel of pathogens from the pit in use to the pit to be de-sledging. After the pit is emptied, the pit cover should be placed in position and the joint made airtight. The humus collected has rich manure value and is a good soil conditioner. The humus from dry pits can be used directly either in the kitchen garden or the fields, but from wet pits it can be used only when it is sun dried.

Do's

- Keep a bucket full of water outside the latrine.
- Keep a 2 litres can in the latrine filled with water for pouring.

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- Before use, pour a little quantity of water to wet the pan so that excreta slide smoothly into the pit.
 - Flush the excreta after use.
 - Pour a little quantity of water; say half a litre, in the squatting pan after urination.
 - The squatting pan should be cleaned.
 - Use minimum quantity of water in washing the pan and latrine floor
 - Wash hands, using soap or ash, after defecation at the assigned place.
 - If any construction defect is observed during the guarantee period, report the matter to the local authority or the construction agency.
 - When the pit in use is full, divert the flow to second pit
 - If the trap gets chocked, rotting should be done from the pan side as well as from the rear side by means of a split bamboo stick, after removing the cover of the drain or junction chamber.
 - Care should be taken when de-sledging the pits located in water or high sub-soil water areas and in the case of combined pits, as the humus may not be safe for handling.

Don'ts

- Do not use both the pits at the same time.
 - Do not use more than 2liters of water for each flushing (if the waste is not flushed with 2liters, pour more water at the specific spots for flushing waste).
 - Do not use caustic soda or acid for cleaning the pan.
 - Do not throw sweepings, vegetable or fruit peelings, rags, cotton waste, and cleaning materials like corn cobs, mud balls, stone pieces, leaves etc. in the pan or the pits.
-
- Do not allow rainwater, kitchen or bath waste to enter the leach pits.
 - Do not provide water tap in the latrine.
 - Do not throw lighted cigarette butts in the pan.
 - Do not de sludge the pits before one and a half years of its being out of use.

10.5. Waste Water Disposal

Where sewer line of the town exists nearby, arrangement is made for waste water disposal into the public sewerage system. Where sewerage system is not available, waste from latrine and urinal blocks are taken into a septic tank and effluent from septic tank discharged into a soakage pit, in subsurface drainage or treated further before it is disposed of in open drain or in natural body of water. Waste water from bathrooms etc., can be discharged into soakage pits or deep bore holes.

Water Supply for Community Latrine, Bath & Washing in Rural Areas

The community water closets require frequent flushing. It is, therefore, necessary that water closets are flushed simultaneously after every one hour through a overhead storage tank with a capacity of 1500 litres. It is also necessary to have storage tank of similar capacity at ground level. For individual household, individual flushing is important but this does not suit for community latrines.

Latrines for Rural Areas

The collection and localisation of excreta without any help of human agency is possible through sanitary latrines. The scattered configuration of houses and financial constraints impose limitation to providing community sewerage system in rural areas. The proposal of providing sanitary latrines in

rural should be formulated keeping in view the privacy, protection against weather, simplicity, safe disposal of excreta and the needs of local people. The availability of water in rural areas is generally inadequate, hand or pour flush latrine is the first choice

Various Excreta Disposal Systems for Rural Areas and Small Communities

The planning of a permanent solution to an excreta disposal problem should take into account several factors such as religious customs, economic standards, general health and education and availability of local construction materials and skill persons.

While making selection for a particular type of installation, local requirements must be kept in view. Sewerage system, owing to its heavy cost, can not be provided in rural area. The flush toilets are thus expensive and far beyond the economic means of the rural areas and small communities. Whatever excreta disposal method is chosen, it should satisfy that it does not contaminate sub-soil water, excreta is not accessible to flies, no handling of excreta is involved, system is free from odour and unsightly conditions and finally the method should be simple and inexpensive.

10.6. Type of Installations

- (a) Several types of privy installations are used to satisfy the needs of the communities. Only two types of privy installations which satisfy above technical requirements are the pit privy and the aqua privy.
- (b) **Leach Pit:** The details of leach pit are discussed in above paras.
- (c) **Soakage pit:** Effluent from aqua privy and septic tanks is received in the soakage pit. Water from bath and kitchen etc is also sometimes disposed of in the soakage pit by providing a screen trap.

A soakage pit is a round hole made in the porous ground to a depth of 2-5 m with a dia of 1.0 m to 2.5 m. (ground dimensions). The walls of the pit are lined with brick, or stone masonry without mortar. The pit is filled with stone filter media. In case the soil of the pit is not porous, the pit will ultimately start overflowing. Even where the soil is porous, overflowing of pits in several cases has been noticed because the pores of the soil get choked with the passage of time. These are the factors which determine the life of a pit. The life of a pit can be 6 years to 10 years. When one pit is filled, second pit is dug and connected with the system. The location of the pit should be carefully made. It should be located on down hill side and at least 15 m away from the source of water. The construction of soakage pit should be discouraged in thickly populated areas where ground water is the source of water supply.
- (d) **Septic Tanks:** Among all the processes discussed above septic tank is considered the most satisfactory unit for the disposal of excreta from houses, institutions, colonies, camps, schools and hospitals where proper drainage system does not exist. In fact the treatment provided by septic tank is a primary treatment of raw sewage prior to its final disposal. The sludge in the tank undergoes anaerobic decomposition resulting in appreciable reduction in volume of sludge. The effluent is, however, by no means should safe and the disposal therefore receive careful consideration. Only about 30% of settled solids are an aerobically digested in septic tanks.

It should be noted that all liquid wastes, including those from bath rooms and kitchens, may be sent to septic tank without endangering its normal operation. Recent research has shown that contrary to former belief, sullage waste can be discharged into septic tanks.

Indian Standard-2470, Code of Practice for Design and Construction of Septic Tanks is against the excessive use of detergents flowing into the tank. The excessive use of detergents is likely to have a

deleterious effect on the functioning of septic tanks and should be avoided. The design illustrated in this standard however, takes in account waste water from baths.

If the tank is well engineered, the effluent will be slightly turbid and shall have low BOD. The effluent is still offensive and is potentially dangerous to health because it contains pathogenic bacteria, cysts and worm eggs which come along with the effluent because these remain unharmed owing to short detention period in the septic tank. Indian Standard 2470 recommends that, under no circumstances should effluent from a septic tank be allowed into a open channel, drain or body of water without adequate treatment.

In order to achieve best results from the operation of septic tank, turbulence in the tank shall have to be avoided. Turbulence proves so serious, particularly in small septic tanks or the tanks which are overloaded, that it causes complete failure of the functioning of septic tank.

When the new tank is put into operations, for ensuring quick biological action, it is necessary to fill the tank with water before allowing the sewage into it and then to seed the tank with some quantity of ripe sludge taken out from some other tank already functioning or some cow dung can be added. The addition of ripe sludge or cow dung, which is in fairly advanced stage of decomposition, supplies bacteria and fungi for rapid fermentation.

(a) Design of Septic Tank:

General Principles:

Tanks are designed to retain the sewage for specified period to slow down the movement of sewage for necessary bacterial action. The tank should be so sized to have length 2 to 3 times the width. Minimum size of the tank shall not be less than 75 cm wide, one metre water depth and liquid capacity of 1 m³.

Although detention period of 24 to 48 hours is generally available when tank is designed under standard practice but the detention period should not be the deciding criteria for the design of septic tank.

Indian Standard – 2470, Code of Practice for Design and Construction of Septic Tanks, Part II, Large Installations recommends the following parameters for the design of septic tanks:

- (1) Plan dimension shall be based on surface loading at peak discharge. Length shall be 2 to 3 times the width. Surface area is designed on the basis of 0.83 m² for flow of 9 lpm.
- (2) Per capita contribution of dry solids to be assumed at 70 g per day.
- (3) Detention period may fall within 24 to 48 hours on an average daily flow of sewage.
- (4) Load may be taken in terms of fixture units; sanitary appliances and each fixtures unit be taken for a flow of 9 litres per minute.
- (5) Each house-hold with 5 members be considered to have 2 fixture units each (*one W.C., one bath and one W.H.B. = 2 fixture units*).
- (6) Estimation of peak discharge is based on 60% of the fixture units discharging simultaneously, except in case of boarding schools with 50 members when it is based on 70% fixture units discharging simultaneously.
- (7) Average temperature of septic tank is assumed as 25°C.
- (8) Capacity required for sludge digestion on the basis of assumption at (2) and (7) is 3.3 m³ per 100 persons.

- (9) Capacity required for storage of digested sludge on the basis of assumption at (2) is 7.67 m^3 (7.30 m^3 as per *Manual on Sewerage*) for 100 persons per year.
- (10) Minimum depth of septic tank is considered to be one metre.
- (11) The baffle wall shall project 30 cm above liquid level. Over-all free board shall be 45 cm above liquid level.

Disposal of Effluent: The septic tank effluent is not of the acceptable quality which can be allowed to run into open drain, in body of water or disposal over land for irrigation purpose. The feasible methods available for treatment and disposal of effluent from a septic tank are dilution, seepage pits, sub-surface irrigation, filter trenches and trickling filters etc.

Limitation of Septic Tanks: Septic tanks are recommended only for individual houses, small communities and institutions whose contributory population does not exceed 300. For larger communities provision of septic tank should be avoided but may be extended to a population of 500 in undulating topography. Fairly adequate water supply is pre-requisite for satisfactory working of a septic tank.

10.7. Septic Tanks

Recommended Sizes and Capacities of Septic Tanks (Number of users less than 50) IS-2470 (Small Capacity)

TABLE:10.1

Number of users	Length	Breadth	Liquid depth D for cleaning interval of			Liquid capacity for cleaning			Sludge to be removed for cleaning interval of			Depth of sludge to be withdrawn for cleaning interval of		
			6 Mths	1 year	2 year	6 Mths	1 year	2 year	6 Mths	1 year	2 year	6 Mths	1 year	2 year
	L	B												
	m	M	m	m	m	m ³	m ³	m ³	m ³	m ³	m ³	m	m	m
5	1.5	0.75	--	1.0	1.05	--	1.12	1.18	--	0.36	0.72	--	0.32	0.64
10	2.0	0.90	--	1.0	1.40	--	1.80	2.52	--	0.72	1.44	--	0.40	0.80
15	2.0	0.90	--	1.3	2.00	--	2.34	3.60	--	1.08	2.16	--	0.60	1.20
20	2.3	1.10	1.1	1.3	1.80	2.53	3.30	4.55	0.72	1.44	2.88	0.28	0.57	1.14
50	4.0	1.40	1.0	1.3	2.00	5.60	7.28	11.20	1.80	3.60	7.20	0.32	0.64	1.28

Note: A provision of 30 cm. should be made for free board.

Recommended Sizes and Capacities of Septic Tanks (Numbers of Users more than 50)

TABLE 10.2

No. of users	Length L	Breadth B	Liquid depth D (for Stated interval cleaning)		Liquid capacity		Baffle
			Yearly or less M	Two yearly m	Yearly or less m3	Two yearly m3	
For Housing Colonies							

100	8.0	2.8	1.0	1.04	22.4	23.3	5.3
150	10.6	2.8	1.0	1.15	28.6	32.9	7.1
200	12.4	3.1	1.0	1.15	38.4	44.2	8.3
300	14.6	3.9	1.0	1.15	56.9	65.5	9.7
For Hostels and Boarding Schools							
50	5.0	1.6	1.3	1.40	10.4	11.2	3.3
100	5.7	2.1	1.4	1.70	16.8	20.4	3.8
150	7.7	2.4	1.4	1.70	25.8	31.4	5.2
200	8.9	2.7	1.4	1.70	33.6	41.0	6.0
300	10.7	3.3	1.4	1.70	49.5	60.0	7.2

10.8. Drains

In Andhra Pradesh, the rainfall is more hence, required elaborate storm water drainage system. Connecting to a soak pit and diverting the excess to the kitchen garden wherever possible can easily dispose off the wastewater generated by the households. Hence, Open drains are to be provided. The open drains are useful for conveying less foul water from kitchens, bathrooms, washing places and rain water from courtyards, roads, roofs, open grounds etc except foul discharge from water closets. The open drains carry away sullage and rainwater up to natural watercourses or discharge it in public sewer. The open drains are mostly laid along the either side of the streets along the boundary walls of the buildings. A typical cross section of drains is shown in fig.10.3.

An ideal drain section should fulfil the following conditions

- It should develop self-cleaning velocity with minimum dry weather flow.
- It should have sufficient free board at its top, even during maximum discharge.
- It should be clean in construction and maintenance.
- It should be such that it can easily be cleaned.
- It should be structurally safe and stable.

There is lack of maintenance of the open sullage drains and misuse by the community who tend to deposit solid waste into the drains, which results in blockage of the drains. Hence, before they choose drains, the community needs to be educated about the maintenance and proper use of the drains before the demand for drains is accepted for the inclusion in the project.

10.9. Layout of drains

Surveying and Data Collection

Drains have to be provided in the lanes and then led off to the disposal point. Hence, survey of the internal lanes in a village is the first step to decide the layout of the drains. During the survey the available width and the length of each lane and the gradient are also noted. The drains provided under the project will closely follow the network of lanes. In the absence of sufficient space for drains on either side of the lane, the paved surface itself has to be designed to act as a drain for storm water. The centre of the lane will act as drain portion. This prevents water entering the sills of the houses. The layout of drains has to be suitable to dispose the sullage/storm water into natural drainage course. Generally, slope of terrain has to be followed and adopted so that the drains to be provided will have uniform depth. Also, it has to be ensured that there is no stagnation of water, which may result in a breeding of mosquitoes causing health hazards. Hence, where there is no natural slope of terrain minimum slope of 1 in 240 may be provided for 200 mm wide drain and 1 in 375 for a drain of 250 mm wide. Wherever possible the drains may be lead to rainwater harvesting structures so that general ground water table is recharged and increase the sustainable yield of wells in the vicinity.

10.10. Solid Wastes – Storage, Collection, Transportation & Disposal

The term solid wastes includes waste products from the kitchen, rubbish containing paper, plastics, wooden pieces, metal pieces, metal and paper containers, broken glass, waste from building construction sites and particularly in rural areas waste products from cow sheds and agricultural activities. The daily output of household waste depends on the life style of the people, dietary habits, living standards and economic status of the people. Unless solid waste is collected and disposed off, the drains will be used for dumping the solid waste leading to chocking of the drains. Solid waste if allowed to accumulate near residential areas would pose a public health hazard due to following reasons:

- The organic matter present in the waste material would decompose and give rise to breeding of flies and other insects. The refuse heaps attracts vermin, rodents, pigs and dogs.
- The insects, flies and pathogens breed in the waste heap would enter the house premises and spread diseases.
- There is possibility of pollution of soil and of surface & ground water.
- Large heaps of refuse near residential areas would cause bad odour and unsightly appearance. Therefore it is necessary to establish an efficient system of collection of solid waste from the residential areas, transport them from the place of living to the disposal site in closed or covered containers and dispose the waste material.

Vermicast production and collection

The worms that feed actively assimilate only 5-10 % and the rest is excreted as loose granular mounds of vermin casting on the surface generally away from the food source. These have to be brushed aside and collected into separate trays. The collected castings have to be left overnight in conical heaps for the worms to move to the bottom. The tops of the cones, which are free of worms, are then collected and lightly air dried. The dried vermicastings are sieved through a 3mm mesh to separate cocoons and young ones from the vermicastings. The dried castings are ready for use as manure. Application of vermicastings to plants is similar as in the case of compost or organic manure. The details of typical compost pit are illustrated in figs 10.4 & 10.5.

Treatment Technologies

The waste waters are ultimately collected at the last point and pumped for subsequent treatment through various low-cost technologies which do not require any mechanical parts and minimal power. Various technologies for treatment of sewage / waste water are enlisted as:

- i) Stabilization Ponds
- ii) Duckweed Ponds
- iii) Treatment by Forestry / Tree Plantation (Karnal Technology)
- iv) Root Zone Technology / Artificial Wetlands
- v) Aerated Lagoons

10.11. Design Guidelines For Under Ground Drainage Schemes

Survey and General Investigation

For preparation of preliminary and detailed project report of sewerage system, it is essential to have precise survey and general investigation of the area. Correct survey is important to arrive at correct decisions. Precise levels indicating the topography are needed for the design of sewer lines, their alignment and location of treatment works. In addition investigation with regard to sub soil conditions

such as type of strata, water table and its fluctuation are also required. The details of underground services like water mains telephone and electric cables and gas lines etc. are also necessary.

In addition to existing features of the town; other investigation of the area likely to be merged in the town boundaries indicating the type of use of land such as residential, commercial, industrial and recreational, density of population, types of industrial units, their effluent quantity and quality and their location of discharge points are also required.

This information can be had from census records, master plans of the towns, land use plans departments.

Plans and Layout

The layout of sewer lines would be planned in such a manner that the sewer line connects each building in every street already existing or likely to come up in future. The laterals or branch sewers to serve future area may not be laid until required but planning must be done in a way that future expansion must be simple and can be completed at a reasonable cost.

A detailed survey plan of area to be sewerred and anticipated areas in future should be prepared. The plan should indicate spot levels and also show elevations and location of all streets, roads, railways, parks and all other important features that can influence the design of sewer lines. It should also indicate proposed location of sewage treatment plants with complete details of elevation and location of any obstacle.

Pumping is costly but it becomes necessary under certain situations owing to topography of the area. A detailed study of topography, loadings, future extensions, location of treatment works will lead to sound design. The cost of construction of sewer increases rapidly with the increase in depth. Efforts should therefore be made to select alignment, which involves less depth.

Manual on Sewerage and Treatment by CPHEEO, Government of India recommends the following scales for various plans and drawings:

a)	Index Plan	1:100,000 or 1:200,000
b)	Key Plan and General layout	1:10,000 or 1:20,000
c)	Zonal plants :	1:2,500 or 1:5,000
d)	Longitudinal Sections	1:500 or 1:1250 or 1:2500
e)	Structural drawings	1:20 or 1:50 or 1:100 or 1:200

Sewer lines should be indicated in thick lines and manholes as small circles, in the plan. L section should indicate the ground level, invert level of sewer line, dia of sewer line, grade, velocity, manholes, actual discharge and designed discharge. Flows should be indicted in liters/sec (lps) or in m³ /hour except for large size sewers, which may be in m³ /sec. Areas on plans should be indicated in hectares (ha).

In the plan, trunk sewer should be marked first and then main sewers and then branches. Understandably where there is junction of two sewers, main sewer is of a large size. The manholes on the trunk sewers are serially numbered as 0, 1, 2, 3, 4 and so on, starting from out fall end (the lower end) and finishing at the top end. Manholes on the mains or branches are again numbered 1, 2, 3, etc prefixing the number of manhole on the main sewer line from the manhole number 3 on the trunk sewer.

The layout of sewer lines would depend very largely on the local topography. The best alignment and grade for the sewer lines would generally be obtained when the proposed sewers follow the natural drainage lines. In case of a town located along a stream, as generally is the case in hilly areas, where

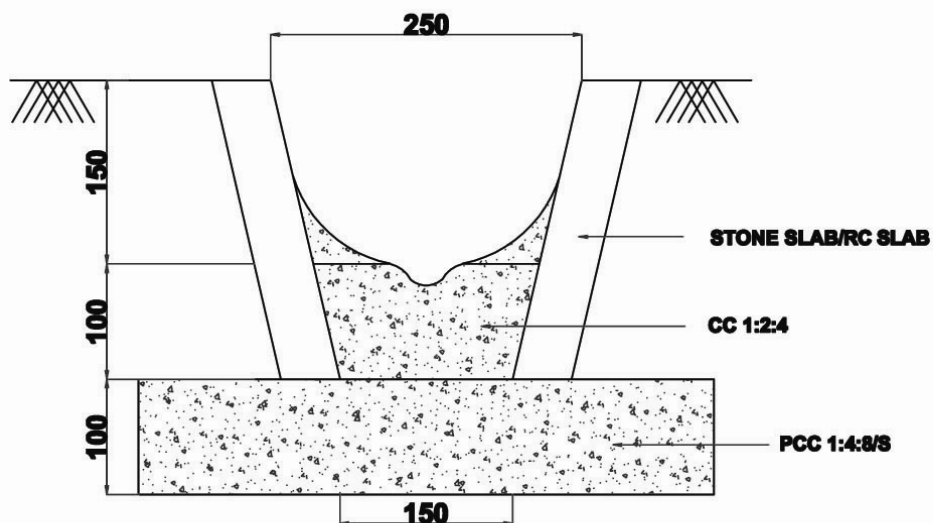
the ground gently slopes towards the stream, trunk sewer is located close to the stream and main sewers run perpendicular to the trunk sewer. Where the town is located in valley converging trunk lines leading to an interceptor may be used. If the town is located on different terraces one above the other or on opposite side of the ridge, a special layout may be required to make the system economical. There are many situations in hilly areas where it is not possible to carry the waste of entire town at one place due to topographical reasons. Under such conditions disposal points will be more than one depending upon the topography of the town.



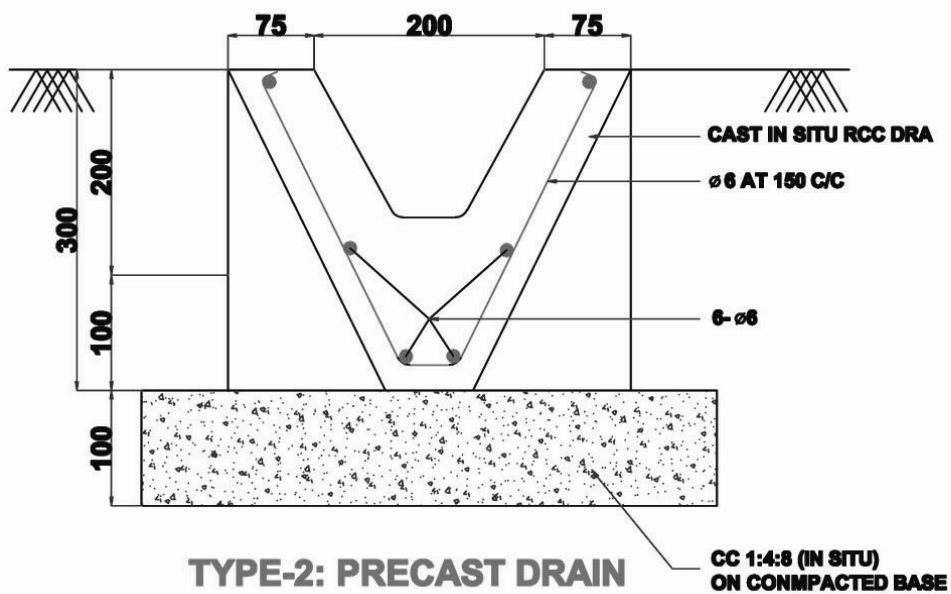
FIG NO. 10.1 : TWIN PIT POUR FLUSH TYPE TOILETS

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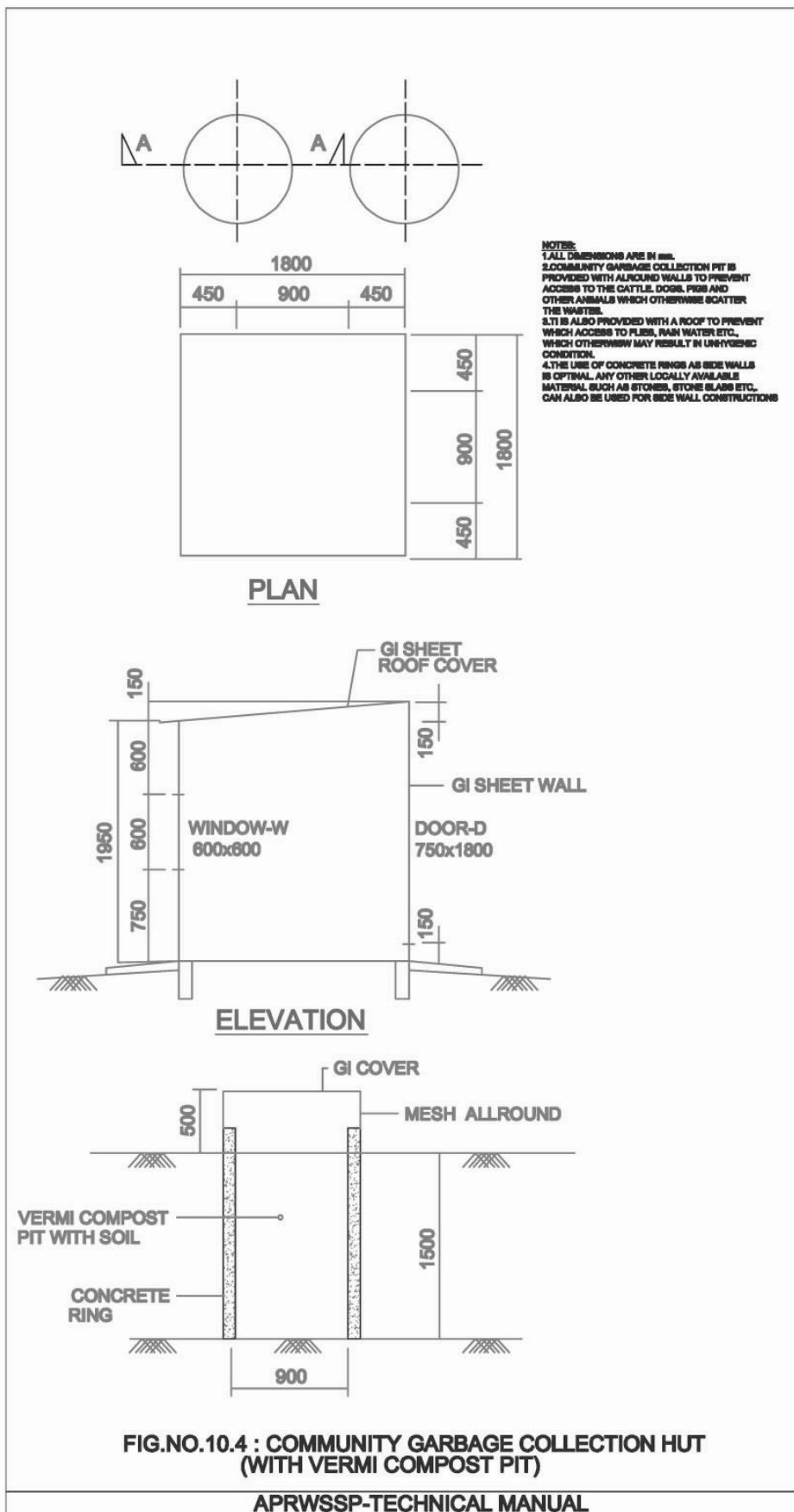
TYPE-1: SULLAGE DRAIN

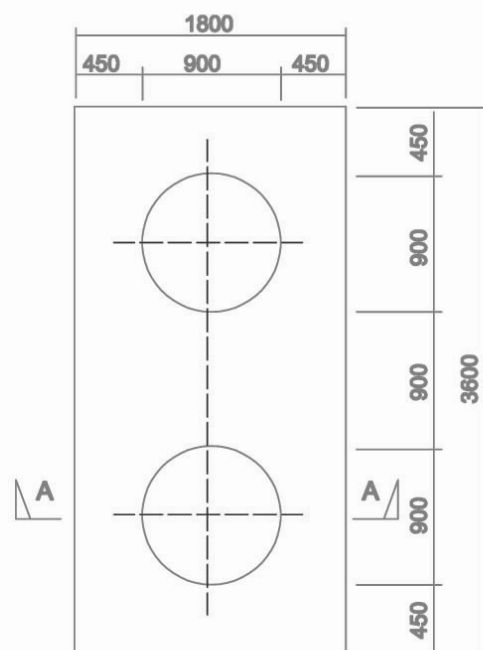


TYPE-2: PRECAST DRAIN

FIG NO. 10.3 : TYPICAL CROSS SECTION OF DRAINS

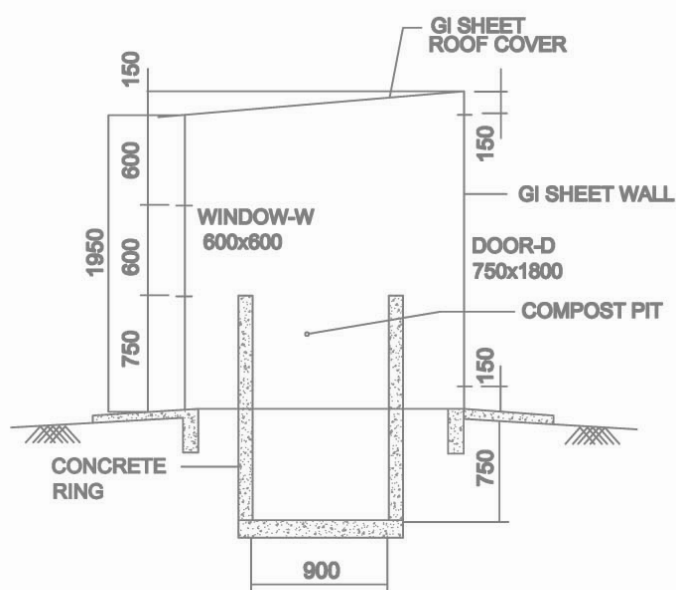
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NOTES:
 1. ALL DIMENSIONS ARE IN mm.
 2. COMMUNITY GARBAGE COLLECTION PIT IS PROVIDED WITH AROUND WALLS TO PREVENT ACCESS TO THE CATTLE, DOGS, PIGS AND OTHER ANIMALS WHICH OTHERWISE SCATTER THE WASTES.
 3. IT IS ALSO PROVIDED WITH A ROOF TO PREVENT WHICH ACCESS TO FLESH, RAIN WATER ETC., WHICH OTHERWISE MAY RESULT IN UNHYGENIC CONDITION.
 4. THE USE OF CONCRETE RINGS AS SIDE WALLS IS OPTIMAL. ANY OTHER LOCALLY AVAILABLE MATERIAL SUCH AS STONES, STONE SLABS ETC., CAN ALSO BE USED FOR SIDE WALL CONSTRUCTIONS

PLAN



SECTION A-A

**FIG.NO.10.5:COMMUNITY GARBAGE COLLECTION HUT
(WITH CHEMICAL COMPOST PIT)**

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CHAPTER – 11

11. GROUND WATER RECHARGE

Rapid growth in industries, large scale lift irrigation schemes, rapid increase in population and frequently prevailing drought conditions have resulted in lowering of ground water table to great extent. If such conditions continue groundwater would be scarce that it would not remain economical to access groundwater. So this situation warns more judicious use of water and waste water.

There has been constant depletion of ground water table and also deterioration in the ground water quality. This situation has arisen due to indiscriminate extraction of ground water for irrigation. This necessitates an urgent need for taking up measures for replenishing the same, to make the source sustainable during the design period. The earlier experiments have proved that the replenishment of ground water is feasible through appropriate techniques. This chapter describes ground water recharge method to be adopted for the water supply sources of the project schemes.

The planning and implementation of ground water recharge treatments structures are specific to condition of the area is found to be producing the tangible results. For this, geo-hydrological, lithological and water quality studies are essential to decide on appropriate approach.

Recharge of ground water takes place when the rainwater infiltrates into the underlying layers. The rate of recharge depends upon the type of soil, intensity and duration of water spread on the ground. Hence, the rate of infiltration and resulting recharge can be improved by checking the speed of the surface run-off and by impounding the water on the surface. Individual wells can also be recharged by directing the surface water through appropriate method into the aquifers connecting to the well.

11.1. Need for Ground Water Recharge

The need for taking up ground water recharge measures has been recognised for:

- The excessive extraction of ground water has resulted in continuous recede in ground water levels, particularly in elevated areas, areas of dry zone and areas where bore wells are extensively drilled by farmers for irrigation. In these areas, additional support to continuous replenishment of groundwater is needed through recharge measures as otherwise the aquifers and the source will dry up, leading to drying up of source developed.
- In many villages, though the ground water exploitation is limited, water fit for drinking is available only in few patches at lower yield level. This is due to presence of clayey soils, hard rocks, rocky layers devoid of fractures, etc., at upper profile where natural infiltration takes place at very low rate. In such cases, recharging of the aquifers by induced infiltration may be the only alternative. This is more required in villages having limited alternative sources of water.
- In some villages, though the yield of bore wells is adequate, they may contain dissolved salts beyond the permissible limits. The recharge measures will help in diluting the dissolved salt concentration and make it portable.

Favorable conditions for recharge

- Formation of sand, gravel, or highly fractured rocks either underground or exposed over a large area or in stream channels and areas of persistent topographic troughs.
- Areas having closure fractures, lineaments, zone of recitation, presence of caverns, fractured or faulted zones or numerous small cavities in rock formations (limestone areas) either under ground or exposed on the land surface or stream channels.
- Contact zones between two or more rock formations and devoid or underground barriers or dykes for horizontal or vertical movement of ground water.
- Feasible location for installation of recharge wells, dams, diversions or other recharge structures.
- Valley extending over different geological formations and wide streams may present excellent opportunities for water spreading.
- Deeper or narrower streams for impounding maximum quantity of water.

Conditions affecting the recharge

- Lining of stream channels and concentration of surface runoff by control projects.
- Sealing of natural recharge areas with impervious sidewalls.
- Diversion of water, which might percolate naturally in the stream channels.
- Presence of dykes, impervious rocky layers, clay soils that do not allow infiltration of water.
- Denudation and lack of check to run-off water which;
- Limit the surface stay of water.

Identification of area for planning of artificial recharge project

The artificial recharge of ground water is normally taken in the following areas:

- Areas where groundwater levels are depleting on regular basis
- Areas where substantial amount of aquifer has already been de-saturated
- Areas where availability of groundwater is inadequate in lean months
- Areas where salinity ingress is taking place

11.2. Methods of Recharge

The ground water recharging technology / methods will have direct or indirect impact and to have maximum result, the technology selection should be suited to the specific condition and acceptance of the local community which is essential to ensure the sustenance of the technology / treatment.

The components/technique with direct impact envisages improving infiltration and recharging through creating conditions for stagnation of rainwater on the surface or sub-surface layers of catchments area of water source point (well) and facilitating the water to percolate into underground layers for recharging the aquifers. This could be achieved through different approaches.

a). Surface Technique

1) Spreading method

These are the most commonly adopted and cost effective methods of recharge. In this technology / methods, water is ponded over the surface area to induce infiltration into sub-soil layers. In this approach, the quantity of water recharged depends on the period of water ponded or allowed for detaining on surface for infiltration. These are most suited to recharge aquifers and semi confined aquifers and effective in the area having good vertical permeability and aquifer transmissibility to transport water away from the spreading area. This is effective if the water table is sufficiently deep and having sufficient fracture area to store the recharged water. These are normally adopted for the integrated watershed development with in-situ conservation works.

Water is applied in areas where the aquifer to be recharged is near ground surface and recharge is achieved through permeable material. In situations where there is a reliable source of good quality input water and spreading infiltration can be operated throughout the year. Evaporation rates from open water surfaces range from about 0.4 m/yr for cool wet climates to 2.4 m/yr for warm dry climates so form a minor component of the water balance for the scenarios described.

However, where the source of water is sporadic from seasonal flow containing high loads of suspended solids, Management of the recharge structure becomes increasingly important in order to maintain infiltration rates and keep evaporation rates from open water to a minimum. Few estimates have been found of the proportion of the water that evaporates from these structures in these situations and this is an area where additional data collection could benefit management strategies greatly.

2) Infiltration of recharge basins

In infiltration basin is either excavated in the ground, or it comprises of an area of land surrounded by a bank, which retains the recharge water (e.g. Storm Water), until it has infiltrated through the base of the basin. If the underlying aquifer is reasonably permeable, a simple dug basin can be used. If in case the aquifer material is fine, or in case of fissure-rock aquifer, rapid clogging will occur. In this case, covering the bottom and sides with an approximately 0.5m thick layer of medium sand can retard the clogging process and extend the recharge periods.

3) Contour trenching

Large numbers of trenches are excavated at a shallow depth throughout the slopes of the foothills. These contour trenches will be able to collect the runoff water from the catchments of the slopes of the hills and further infiltrate down the water collected the pits to the groundwater reservoir. These pits will also accumulate detritus material along with soil, which will be ideal material for afforestation activity.

4) Recharge through Ditches/Trenches

This method is applicable when transmissibility of water bearing strata is low. On streambeds, where check dams have been constructed and the geological structure favours infiltration, trenches may be dug perpendicularly to the fractures so as to intercept the flow and induce infiltration. These trenches to be filled the gravel and coarse sand at the top half to act as filter bed. The size of the trenches depends on the space available within the storage of the impounding structure and fracture system. The depth may be around 3 meters. The spacing between ditches could be about 2 m. The ditch can be excavated in slight gradient to maintain flow velocity and minimum deposition of sediments. The ditches will be provided

with 15 to 25 cm of washed gravel or crushed stone after every monsoon, the slit on top layer up to depth of situation needs to be cleared to remove clogging and to maintain the level of infiltration.

5) Recharge through Ponds

This method is recommended when the transmissibility of the soil is high. A single pond of large size can serve the purpose. The size of the pond can be decided depending upon the volume of source water available.

6) Recharge through Percolation Tanks

These are most prevalent structures in India as a measure to recharge ground water reservoirs both in alluvial as well as hard rock formations. The efficacy and feasibility of these structures is more in hard rock formation where rocks are highly fractured and weathered. Percolation tanks are the most prevalent and widely adopted method in India to recharge ground water both in alluvial and hard rock formations by constructing storage reservoirs in gently sloping and flat terrain where the valley is broader. Under this approach, earth is removed from valley portion and heaped against valley flow to create the tank. The down stream of pond may be protected by stone masonry. The efficacy of these structures is found more in hard rock areas having weathering and fractures. These are also suitable in basaltic lava flows and crystalline formations. These with infiltration wells and recharge shafts are found much effective to recharge the deeper aquifers and in the area where upper or superficial formations are highly impermeable or clay as in black soils.

7) Check Dam

Check Dams are constructed in the drainage course of narrow streams in low rainfall area to impound run-off rainwater (Fig 11.1). These are made of masonry structure and designed to store maximum water available from run-off (for surface storage or ponding). The size of the check dam generally depends on the height of the stream bank and width of the stream. The height of dam is generally half the height of the bank and designed in such a way that water does not spill over the bank during the high floods. The dams normally get filled from rain water three to four times a year and seep into underground aquifers. The check dams normally need maintenance by de-silting to maintain the storage and recharging capacity. The drainage course having deep layers of clay as in black soil areas; it is product to open a pit/recharge trench of convenient size until the reach of hard rock and filling it with filter material to indicate direct infiltration of water into the fracture zone. These pits are to be made after identifying the fractures through geo-physical survey to ensure direct infiltration of water and recharge.

Points to be considered in construction of Check Dams and Percolation Tanks

- Analysis of rainfall pattern, number of rainy days, dry spells evaporation loss and detailed hydro geological studies to locate the percolation tanks.
- In semi and arid areas the size of percolation tank is designed such that the water percolates to ground water aquifers before the summer when the evaporation loss increase substantially.
- Percolation tanks may be located on second to third order stream since both catchments would provide enough water and the area of submergence is uncultivable and be smaller as far as possible.

- This should be located on fractured and weathered rock for speedy recharge. In the alluvial area the recharge boundary should have well for utilization of the impact.
- The recharging area should have sufficient thickness of permeable zone to accommodate recharge and number of wells and cultivable area to make use of the water recharged.
- The run-off assessment should be done for designing the percolation tank and its capacity should not be normally be more than 50% of the total rainfall in the catchments.
- The spill way should be designed and constructed to dispose the surplus water in case of large inflow due to torrential rainfall.
- The vegetative checks are provided in the upper reaches of tank to check situation and to sustain it efficacy.
- The people having interest in the recharge and discharge area should be involved to insure proper management of the tanks and maximise its impact.

8) Nalabunds

Nalabunds are like check dams constructed across small stream where insufficient soil cover is present and made with puddle clay instead of masonry structure. For construction, the soil is removed from the stream course and a bund is put across to check the free flow of water in the Nala. This will help to augment the ground water source in the region. For construction of nalabunds the following are to be considered.

- The total catchments of the stream should be between 100 to 250 acres.
- The rainfall in the catchments should be less than 1000 mm per annum.
- The width of the stream should not exceed 15 m and should not be less than 15 m and the depth of the bed should at 1 meters.
- The soil in down stream should not be prone for water logging and should have rechargeable well and irrigable areas.
- The Nala bunds generally small earthen dams should be preferably located in the area where its catchment is treated with in-situ conservation works to check the situation.
- The stream strata of the impounded area of Nala bound should permeable to affect ground water recharge.
- Normally the dimension of the Nala bund varies between 10 to 15 meters, height 2 to 3 meters and width 1 to 3 meters and constructed in trapezoidal form. If the bedrock is highly fractured the cement grouting is done to make the foundation leakage free.

9) Roof Top Rain Water Harvesting

In areas where no piped water supply is available and the groundwater system has inadequate storage capacity to sustain water supply in the summer months, or the quality of ground water is unfit for drinking, rainwater harvesting can be a good solution. Sometimes a river or stream is not close at hand or the soil is not deep enough to sink a well. In these cases rainwater harvesting can be the only way to provide for domestic purposes. Rainwater harvesting is also used in addition to existing water supplies. A model of roof top rain water harvesting structure is shown in fig 11.2.

A well can provide enough water for up to 250 people and would be a good water supply for a small community. However, when families are scattered across the land and a dirty puddle or stream is nearer, those families might not use the clean well around the whole year. In these cases a personal supply system would be preferred. In the rural areas, a piped system is much too expensive and maintenance could be a huge problem. The rain water harvesting is one of the ground water recharge methods suggested for arid and semi-arid areas. In this technology the rain water from rooftop will be diverted to recharge pit dug up to

infiltration zone and having proper filter bed to impound water directly to the aquifer zones. These are implemented where people accept such technology and the geological structure favours infiltration. Rain water harvesting is not recommended in the area of deep black soils or where soil collapses when attains water saturation.

a). Sub-surface Technique

These could be implemented in the locations which are favourable for direct injection of surface water into the aquifer layers, through the techniques like open injection wells, positioning of gravity head recharge wells, aquifer storage and retrieval systems and Soil aquifer treatments.

These are effective in case of definite sources of surface water available at identified locations for longer period for injecting and improving the infiltration into ground water. It is most ideal for areas where rainwater and base flow is available for longer period to induce its flow into underground layers. The impact of these methods will be nominal in dry zones where the rainfall and surface flow is limited. Schematic diagrams of recharge through wells and bore wells are shown in fig. 11.3, 11.4, and 11.5

1) Sub-surface dykes

In the area of gentle slope, where the bed rocks are available at shallow depth and the stream or valley is filled with pervious material, sub surface dykes are said to be effective to check the base flow and induce infiltration. These are successful if the catchment area has sufficient rainfall and better permeable profile on upstream. In these locations, the subsurface dam across valley flow can be constructed through an impervious wall with materials like puddle clay, concrete masonry structure, mud-dam supported by polythene sheet at upper side of the stream are on the dyke section itself depending on the area of influence. The wall of the dyke will be thin and this does not need any buttresses, as the passive earth pressure of the soil will take up the water pressure. Besides, the structure is finished at 1 meter below the flowing surface of stream to provide room for maintenance of riparian rights of the downstream farmers.

The sub-surface dykes are found to be effective in areas covered by sedimentary rocks where streams are wider with higher flat level exist and upper catchment permits the steady flow of underground water to permeable aquifers. The approach is ideal to recharge where the ground water table is deep and heavily drafted.

The construction of sub surface dams in wider streams of carrying sufficient water facilitates to arrest the movement of ground water from the basin and harvest for increasing the seepage to ground water sources. These structures are to be built in narrow gently sloping valleys where the bed rock occurs at shallow depths and valley fill consisting of 4 to 8 metres of thick pervious material. The sub-surface dams across such valleys will collect flowing water and convert them into water sanctuaries and supplement the depleted resources and rejuvenate the aquifers for stabilizing water levels.

2) Recharge through wells and Shafts

This method is suitable when there is impervious surface having considerable depth, subsurface soil being pervious. In such situations a well could be constructed through impervious strata. The dia of such a well could be from 150-300 mm. A well of larger

diameter could be constructed if need be and in that case it is called a shaft or a pit when it is large but of irregular shape.

3) Subsurface Drainage

For very large project and extensive area of infiltration, it may be necessary to provide the area with subsurface drainage in the form of a few lateral open trenches or pipeline drainage into an out fall drain. Normally 100-150 mm open jointed drains are placed 1.5-2.0 m below the surface and a suitable interval depending upon the permissibility of the soil. This arrangement improves the rate of infiltration to great extent.

11.3. Point Recharge of Individual well

Recharging of individual / specific well could be achieved by passing of water to the identified connecting / linked fracture zone or lineaments through a filter bed to check clogging at filtration zone. Abandoned wells both open and bore well could easily be used for this if available in its feeding zones. To use the abandoned well (bore), casing will be extended up to ground level and its surroundings will be filled with graded gravel or filtering material and the surface water will be diverted into it the well through this. The filtering material at well mouth is to filter the suspended material and allow clear water to get in. In this technology, the recharge will be faster since good head is available for the flowing water.

The point recharge could be taken up through abandoned pit, tanks and stone/rock mined depressions available in the watershed/recharge area for creating artificial impounding to store rainwater. In the villages smaller infiltration pits could be proposed in the flow lines and in the mouth of storage cum delivery systems under mini water supply schemes to induce the infiltration of flowing water directly into aquifer zone. This would also benefit to keep the area cleaner in the villages and to ensure sustenance of water source.

In case the abandoned wells are not available, a filter bed of 3 m square could be dug to 2 to 3 m depths and filed with filtering material near the source well. A passage would be made from this pit and connected to the pumping well through a 30 mm diameter pipe from the bottom of filter bed. This is to check the entry of silt and allow clear water to in-filter to maintain purity of water and porosity of the well.

Indirect methods of Recharging

The other approach proposed is through infiltration gallery, made by opening of trenches / holes perpendicular to the fractures in the Nala beds to intercept the fractures wherever possible. These trenches are later filled with gravel and granular material having good infiltration characteristics to maintain the rate of infiltration and recharge. However, it has been indicated that the integrated in-situ conservation coupled with runoff harvest is the best form of indirect approach to improve ground water recharge.

11.4. Structures to recharge ground water from village drainage

The harvesting of rain water in the drainage area of the village in the village tank or natural depression could be attempted as one of the ground water recharge methods to recharge and sustain the water yield of bore well situated in the village will be diverted to a recharge pit dug up to infiltration zone and having proper filter bed to impound water in the vicinity of village and infiltrate directly to the aquifer zones. These could be ideal in the area where people accept such technology and the lithology favours increased infiltration. However, rainwater harvesting is not recommendable in the areas of deep black soils or where

soil collapse when soil attains water saturation as these may lead to destabilize the building structures of rural areas.

The run-off harvesting structures in drainage course at appropriate points are the effective technology which could be adopted in the project to ensure ground water recharge. Other components can be proposed and got implemented by beneficiaries through motivation.

11.5. Steps to be followed for implementing ground water recharge treatment

The villages qualifying for ground water recharge should conduct the following studies for planning and implementation of recharge components.

- Geo-hydrological condition of the area based on the Topo-sheets overlaid on the satellite imagery to understand the ground water prospects. The studies available with Departments could be made use.
- The study of litho logical formations and geological disturbances based on the available secondary data.
- The analysis of rainfall pattern, cropping pattern, water table fluctuations and the hydraulic gradient of ground water to understand the behaviour of ground water environment.
- Delineating recharge area of water source point using the topo-sheet and satellite imagery.
- Estimation of surface supplies from rainfall and other water storage structures to project the availability of water for recharging.
- The time (length) to which the surface source is available for recharging.
- Infiltration rate/capacity of the area through the degree of weathering porosity and permeability in drainage course should be studied to estimate the capacity.
- A study and documentation of the hydro-geological aspects of the area to be conducted which includes: Mapping of the recharge/watershed area and hydro-geological aspects on the basis of water bearing capabilities, both at shallow and deep layers of the area, mapping the ground water contours to estimate the water table and hydraulic connections of water with river etc. Mapping the depth of water table for maximum, minimum and mean annual position as well as amplitude of fluctuation. Map showing the level of ground water utilization.

In addition, it can also facilitate-

- Interpretation of the lineaments, fault zones, dyke intrusions and dipping structures will be analysed using the satellite imagery.
- Stratification of aquifer system and spatial variability of hydraulic conductivity of the area as suitable or unsuitable for recharge.
- Identification of the vertical hydraulic discontinuities such as dykes and fault zone
- Assist of Moisture movement and in-filtration capacity of the unstructured zone
- Identification of direction of ground water flow under natural/artificial recharge process

The quality of the ground needs to be analysed and to be correlated with sources available in the well of connected aquifer to analyse the presence of TDS and fluoride causing mineral veins in the fractures.

11.6. Criteria for selection of site for construction of recharge structure

The selection of site for construction of recharge structure should be made considering the following:

- The selected site should have litho logically jointed lineament connection to the aquifer leading fracture zones as confirmed by the geo-physical survey.
- It should be made after confirming the absence of large deposit of fluoride and TDS causing mineral veins in the fracture zones since recharging through such fractures would increase the fluoride content in water.
- The site should have sufficient catchment area to collect and impound water.
- The site should impound maximum quantity of water at minimum cost.
- The site and its catchment should sustain the impounding capacity of the structure.
- The soil structure should have sufficiently harder strata and sides to stabilise the structure and ensure its sustainability.

11.7. Strategies for implementation of ground water recharge treatment

The implementation of ground water recharge treatment would be people-centred in planning, implementation and management. The support agencies appointed for the village will study the geological features and identify the aquifer and suggest the appropriate recharge point along with required supportive treatments to GP and GPWSC. The support agency would facilitate for discussion in the GP and GPWSC level, draw detail design of the treatment and co-ordinate with GP for implementation. The GP and support agency would also co-ordinate with ZP for taking complimentary/supportive treatment in the recharge area under other State funded programmes to ensure sustenance of recharge impact.

The entire ground water recharging aspects would be under the preview of GP and the support agency appointed for extending community development and technical support will assist on social engineering and technical aspects. The project does not envisage having separate institutional arrangements for implementing these components.

Calculation of Roof Flow Loads and Surface Flow

When designing drainage systems for roofs, it is necessary to find out the level and frequency of rainfall intensity for the location of the house concerned. It is generally satisfactory to design to a rainfall intensity of 75mm/hour where overflow will not cause damage within the house i.e. eaves gutters.

Allowance for the effect of wind is not required when designing for horizontal surfaces or other surfaces protected from the wind by nearby objects. However, an allowance should be considered where sloping or vertical surfaces occur that are freely exposed to the wind.

Cost of Rainwater Harvesting

The cost of rainwater harvesting depends on

- Geographical Location of the village
- Rainfall intensity
- Ground condition
- Structure used for recharge or storage
- Material used for Conveyance
- Roof flow loads

Depending on the situation and condition and use of the most locally available materials and workmanship for construction of such structures, the cost of rainwater harvesting could range from Rs. 10/m² to Rs.100/m².

Effectiveness of the Technology

In most cases, a rainwater catchments system cannot meet demand during extended dry periods. Hence, it is often necessary to have an alternative source to supplement the rainwater supply, rainwater may be the only available source of water in some locations.

It is usually possible to harvest a maximum of 75% of the average rainfall within the area, provided there the rain is not in the form of a very short duration and low intensity, and should not be accompanied by high velocity winds.

Advantages and Disadvantages

Advantages

- Rainwater harvesting systems provide water at the point where it is needed.
- The systems may be owner operated and managed.
- The systems also provide a water supply buffer for use in times of emergency or breakdown of the water supply systems, particularly during natural disasters.
- The system also provides a good supplement to other water sources, and relieves pressures on other water sources.
- Construction, operation, and maintenance are not labor intensive, and the physical and chemical properties of the rainwater may be superior to those of groundwater or desalinated water that may have been subjected to contamination.
- A catchment area, usually a roof of 20 square meters or above is sufficient
- Reduces the cost of pumping of ground water
- Rainwater harvesting improves the quality of ground water through dilution when recharged to groundwater.
- Roof top rainwater harvesting is less expensive
- In hilly terrains, rainwater, harvesting can be preferred
- In saline or costal areas, rainwater provides good quality water and when recharged to groundwater it reduces salinity and also helps in maintaining balance between the fresh saline water interfaces.

Disadvantages

- Rainwater harvesting systems are completely dependent upon the frequency and amount of rainfall. There will be shortages during dry spells or prolonged droughts which can be exacerbated by low storage capacities.
- In areas where the amount of rain fall is very low and the total number of rainy days being restricted the all the water needs to be collected during this short period and stored for future use which is after a total gap which may be as long as 4 months.
- In case of delayed monsoon, and draught period there is no provision.
- Water may contaminate if the storage tanks are not adequately covered, and uncovered or poorly covered storage tanks can be unsafe for small children.

Contamination can also occur from dirty catchment areas coupled with lack of treatment may lead to health risks.

- In the case of community systems, people have to walk significant distances for water if a distribution system is not in place. All systems require maintenance to minimize wastage through broken gutters, drainpipes, leaking storage tanks for outlet taps.

11.8. Standard Rainwater Harvesting Model for Rural Areas

The system may comprise of an eaves gutter collecting water from the roof run-off and sloping towards one corner, and inflow pipe with bypass taking off from the lowest end of the eave's gutter leading to simple mesh followed by sand filter and finally discharging into a tank. Installed inside the basement of house or outside the house, with overflow system to drainage in case where the excess water enters the tank. Chlorination is required in the case where rainwater is directly used for consumption. Rainwater stored for a long period of time without treatment developed bacterial growth but still free of undesirable chemicals. However, bacteria can be removed by simple chlorination.

- For large houses with flat roofs or roofs with varied slope directions. Rainwater from the house roof is collected. In a storage vessel or tank for using during the periods of scarcity. Usually these systems are designed to support the drinking and cooking needs of the family at the doorstep. Such a system usually comprises a roof, a storage tank and guttering to transport the water from the roof to the storage tank. In addition, a first flush system to diver the periods and a filter unit to remove debris and contaminants before water enters the storage tank are also provided.
- Store the rooftops rainwater in tank; water can be withdrawn using hand pump or electric motor pump. Water is then treated using Horizontal Roughing Filter (HRF) and slow sand filter (SSF). HRF usually consist of filter material like gravel and coarse sand that successive decrease in size from 25 mm to 4 mm. HRF is able to reduce turbidity to the levels that allow a sound and efficient SSF, as the final treatment stage, substantially reduces the number of microorganism present in the water. This model can also be used if ground water is contaminated.

11.23. Practices in vogue in AP for ground water recharge:

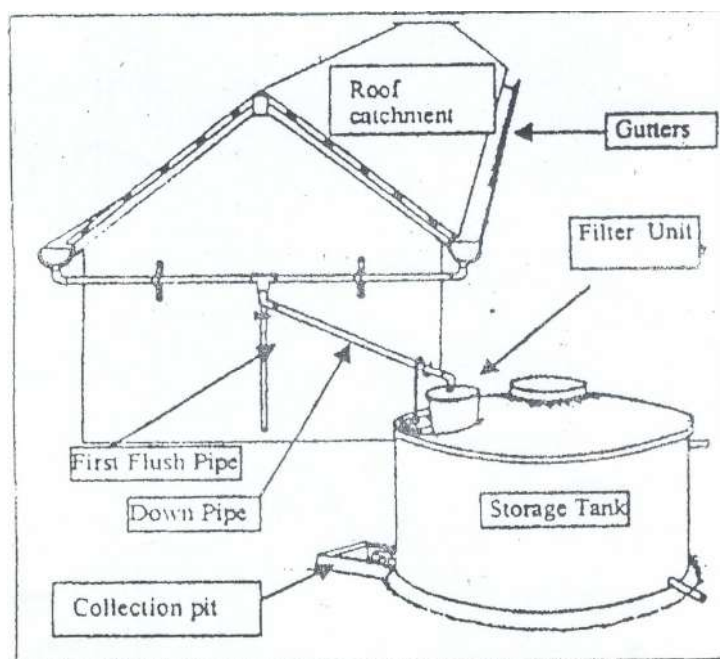
The RWS&S department has taken up different types of water harvesting structures depending on the site conditions since 2000 as per the details given below.

- Check Dams
- Percolation Tanks
- Sub-surface Dykes
- Rooftop Rain Water Harvesting Structures
- Infiltration Rings
- Recharge Pits
- Injection Wells/Recharge Wells

The check dam constructed at Savaigudem, Mahaboobnagar District is shown in photo 11.1.

The root top harvesting structures constructed in Nalgonda district have given drinking water for 90 days. The model of roof top harvesting structure is shown in fig 11.2.

Model of Roof Top Rain Water Harvesting Structure



A typical Rooftop Rainwater Harvesting System

The sub surface dyke and infiltration well at Kothapalli, Medak district has increased discharge by 250 lpm after construction of sub surface dyke.

The sub surfaced dyke across pedda vagu at Janakampeta, Nizamabad district has increased the discharge by 1000 lpm after its construction as shown in the picture below.

Sub-Surface Dyke across Pedda Vagu at Jankampet, Nizamabad District



Estimated Cost: Rs.6.00 Lakhs

Year of Completion: 2002

Length of the Sub-Surface

Dyke: 300 mts

Distance of Infiltration Wells from Sub-Surface

Dyke: 30 mts

Discharge in the Infiltration Wells before Construction

Sub-Surface Dyke: 1500 Lpm

Discharge in the Infiltration Wells after Construction of

Sub-Surface Dyke: 2500 Lpm

Check Dam, Savaigudem, Mahaboobnagar District



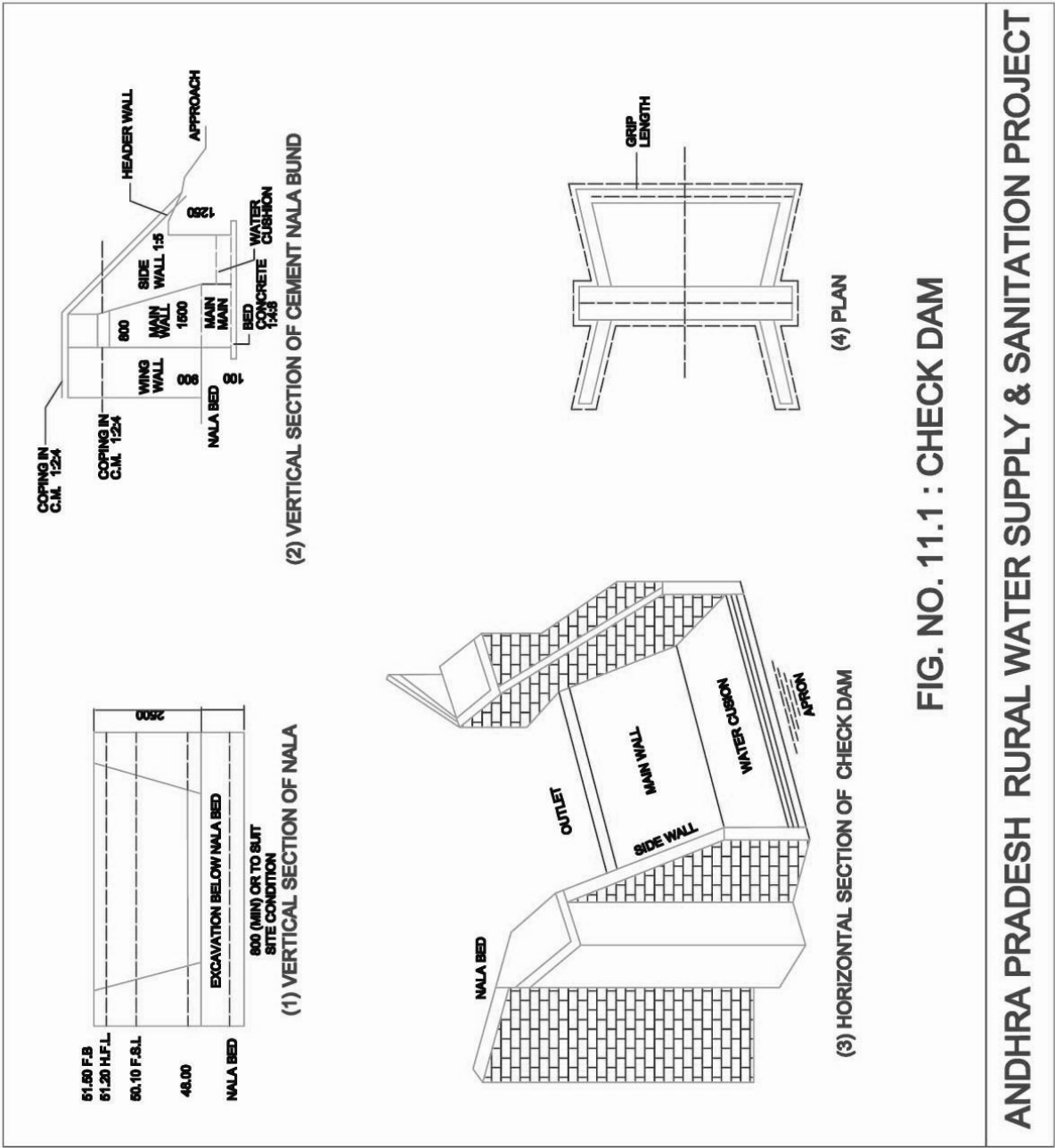


FIG. NO. 11.1 : CHECK DAM

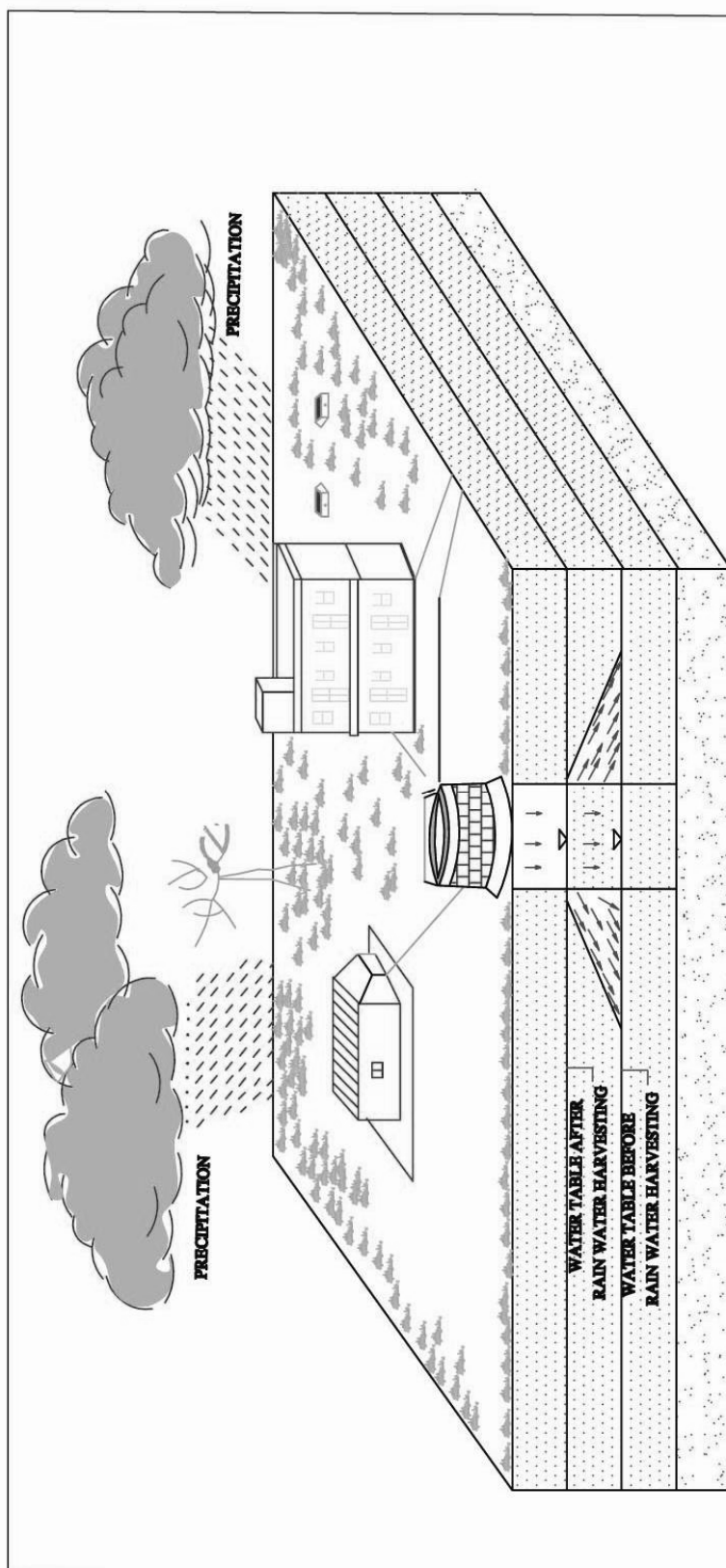
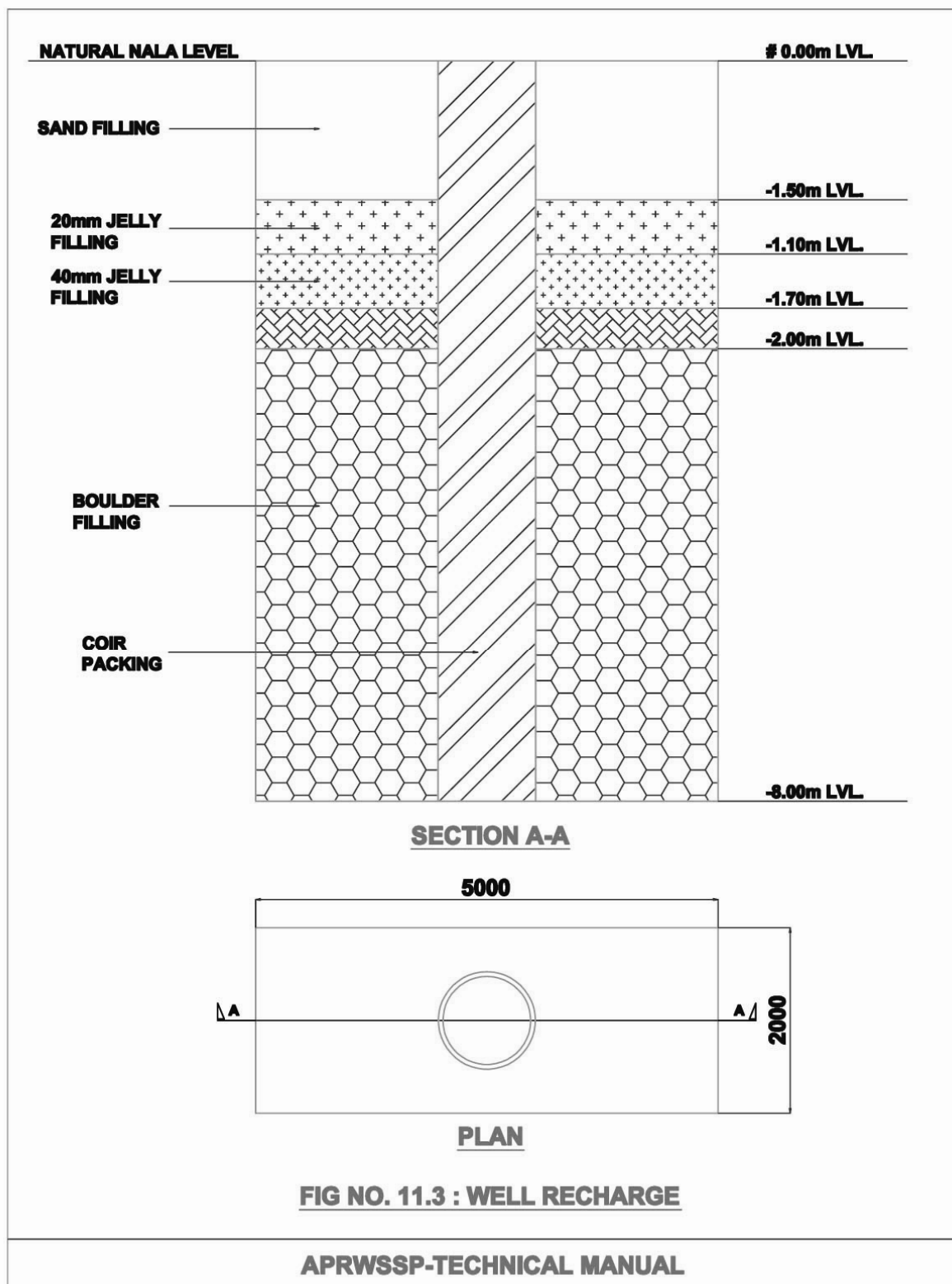
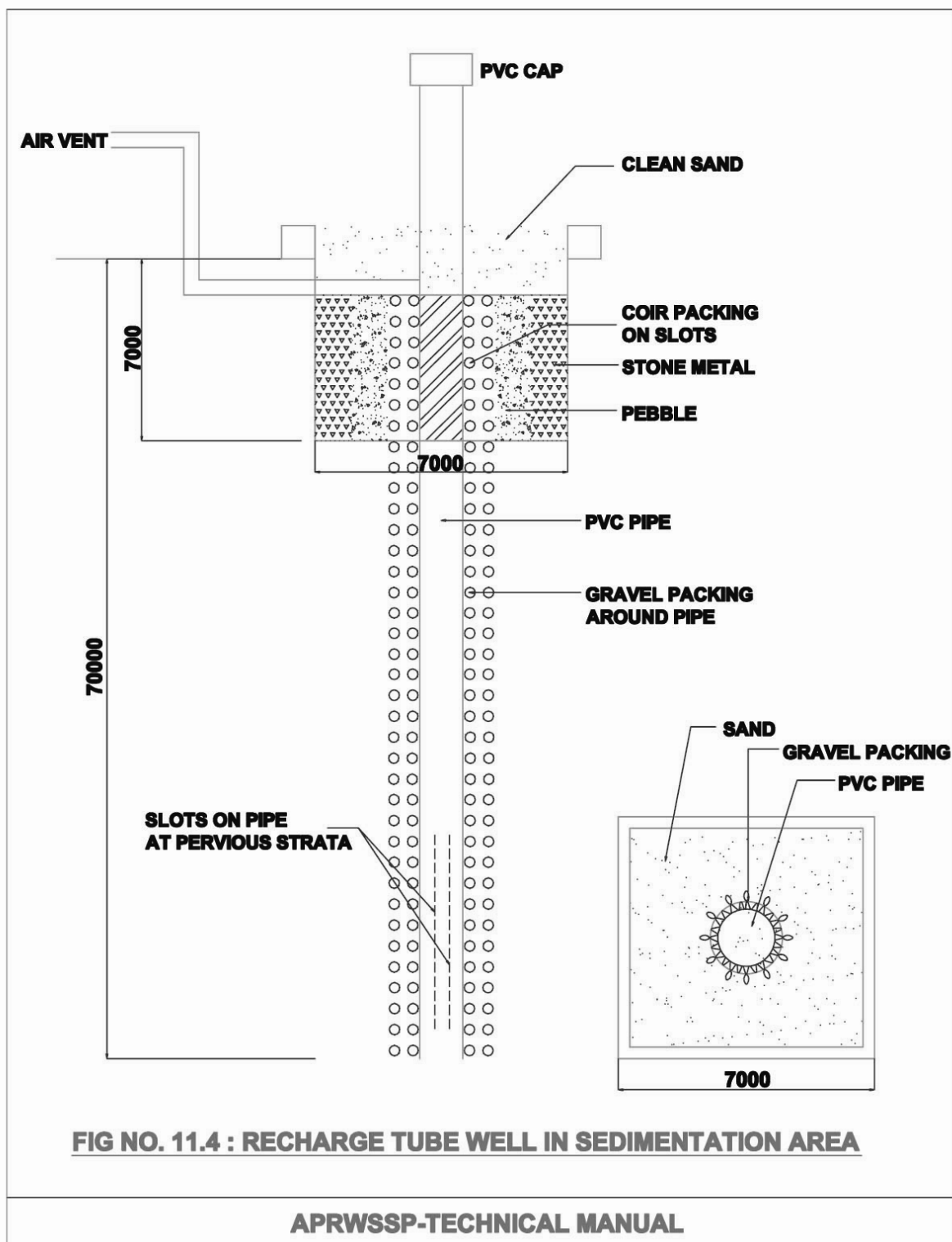


FIG. NO. 11.2 : ROOF TOP RAIN WATER HARVESTING

ANDHRA PRADESH RURAL WATER SUPPLY & SANITATION PROJECT





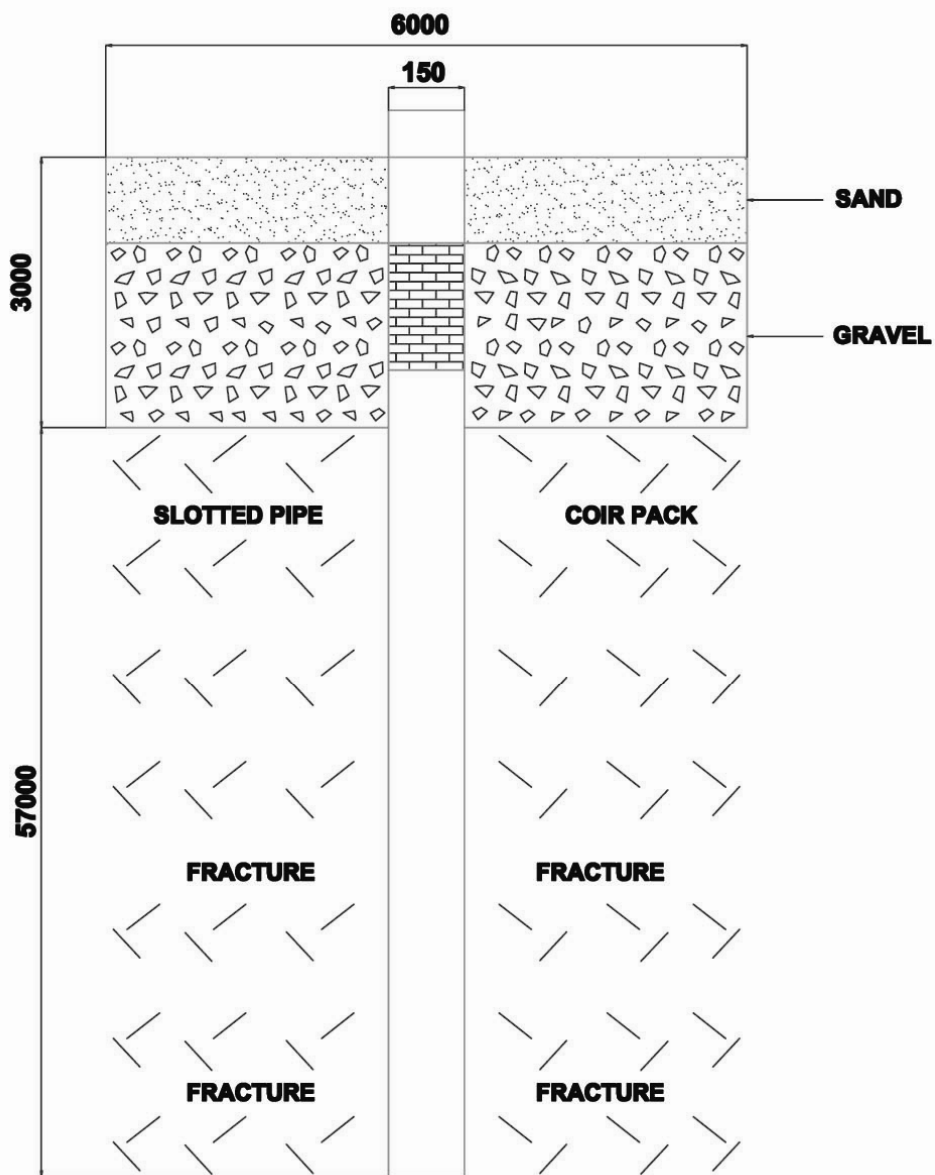


FIG NO. 11.5 : RECHARGE BOREWELL IN HARD ROCK AREA

APRWSSP-TECHNICAL MANUAL

CHAPTER – 12

12. TECHNICAL SPECIFICATIONS FOR MATERIALS

12.1. Bricks

The bricks are obtained by moulding clay in rectangular blocks of uniform size and then by drying and burning these blocks

Qualities of good bricks:

The good bricks, which are to be used for the construction of important structures, should possess the following qualities.

- The bricks should be table-moulded, well-burnt in kilns, copper-colored, free from cracks and with sharp and square edges. The color should be uniform and bright.
- The bricks should be uniform in shape and should be of standard size.
- The bricks should give a clear metallic ringing sound when struck with each other.
- The brick when broken or fractured should show a bright homogeneous and uniform compact structure free from voids.
- The bricks, when soaked in cold water for a period of 24 hours, should not absorb water more than 20 percent by weight for first class bricks and 22 percent by weight for second class bricks.
- The bricks should be sufficiently hard. No impression should be left on brick surface, when it is scratched with finger nail.
- The bricks should not break into pieces when dropped flat on hard ground from a height of about one metre.
- The bricks should have low thermal conductivity and they should be sound-proof.
- The bricks, when soaked in water for 24 hours, should not show deposits of white salts when allowed to dry in shade.
- No brick should have the crushing strength below 5.50 N/Sq.mm.

Strength of bricks

Factors affecting the strength of bricks:

- Composition of brick earth;
- Preparation of clay and blending of ingredients;
- Nature of moulding adopted;
- Care taken in drying and stacking of raw or green bricks;
- Type of kiln used including type of fuel and its feeding;
- Burning and cooling processes; and
- Care taken in unloading.

The shearing strength of bricks is about one-tenth of the crushing strength. In practice the bricks are not subjected to the tensile stresses. It may be noted that the strength of brickwork mainly depends on the type of mortar used and not so much on the individual strength of the bricks.

Tests for bricks

A brick is generally subjected to the following tests to find out its suitability for the construction work:

- | | |
|-------------------------------|--------------------|
| (1) Absorption | (5) Shape and size |
| (2) Crushing Strength | (6) Soundness |
| (3) Hardness | (7) Structure |
| (4) Presence of soluble salts | |

(1) Absorption: A brick is taken and it is weighed dry. It is then immersed in water for a period of 16 hours. It is weighed again and the difference in weight indicates the amount of water absorbed by the brick. It should not, in any case, exceed 20 per cent of weight of dry brick.

(2) Crushing Strength: The crushing strength of a brick is found out by placing it in a compression testing machine. It is pressed till it breaks. As per IS: 1077-1957, the minimum crushing or compressive strength of bricks is 3.50 N/Sq.mm. The bricks with crushing strength of 7 to 14 N/Sq.mm are graded as A and those having above 14 N/Sq.mm are graded as AA.

(3) Hardness: In this test, a scratch is made on brick surface with the help of a finger nail. If no impression is left on the surface, the brick is treated to be sufficiently hard.

(4) Presence of soluble salts: The soluble salts, if present in bricks, will cause efflorescence on the surface of bricks. For finding out the presence of soluble salts in a brick, it is immersed in water for 24 hours. It is then taken out and allowed to dry in shade. The absence of grey or white deposits on its surface indicates absence of soluble salts. If the white deposits cover about 10 percent surface, the efflorescence is said to be slight and it is considered as moderate, when the white deposits cover about 50 percent of surface. If grey or white deposits are found on more than 50 per cent of surface, the efflorescence becomes heavy and it is treated as serious, when such deposits are converted into powdery mass.

(5) Shape and size: In this test, a brick is closely inspected. It should be of standard size and its shape should be truly rectangular with sharp edges. For this purpose, 20 bricks of standard size (190 mm x 90 mm x 90 mm) are selected at random and they are stacked lengthwise, along the width and along the height. For good quality bricks, the results should be within the following permissible limits:

- | | |
|--------|-----------------------|
| Length | : 3680 to 3920 mm, |
| Width | : 1740 to 1860 mm, |
| Height | : 1740 mm to 1860 mm. |

(6) Soundness: In this test, the two bricks are taken and they are struck with each other. The bricks should not break and a clear ringing sound should be produced.

(7) Structure: A brick is broken and its structure is examined. It should be homogeneous, compact and free from any defects such as holes, lumps, etc.

12.2. Cement

The artificial cement is obtained by burning at a very high temperature a mixture of calcareous and argillaceous materials. The mixture of ingredients should be intimate and they should be in correct proportion. The calcinated product is known as the clinker. A small quantity of gypsum is added to the clinker and it is then pulverized into very fine powder which is known as the cement. The ordinary cement contains two basic ingredients, namely argillaceous and calcareous. In argillaceous materials, the clay predominates and in calcareous materials, the calcium carbonate predominates.

Properties of Cement

Following are the important properties of good cement which primarily depend upon its chemical composition, thoroughness of burning and fineness of grinding:

- It gives strength to the masonry.
- It is an excellent binding material.
- It is easily workable.
 - It offers good resistance to the moisture.
 - It possesses a good plasticity.
- It stiffens or hardens early.

Fields tests for cement

Cement shall unless otherwise specified conform to the latest edition of IS-269/1965. Following four field tests may be carried out to ascertain roughly the quality of cement:

- (1) Colour
- (2) Physical properties
- (3) Presence of lumps
- (4) Strength

(1) Colour: The colour of cement should be uniform. It should be typical cement colour i.e. grey colour with a light greenish shade. This is not always a reliable test. But it gives an indication of excess lime or clay and the degree of burning.

(2) Physical properties: The cement should feel smooth when touched or rubbed in between fingers. If it is felt rough, it indicates adulteration with sand. If hand is inserted in a bag or heap of cement, it should feel cool not warm. If a small quantity of cement is thrown in a bucket of water, it should sink and should not float on the surface. A thin paste of cement with water feels sticky between the fingers. If the cement contains too much of pounded clay and silt as an adulterant, the paste will give an earthy smell.

(3) Presence of lumps: The cement should be free from any hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere. Any bag of cement containing such lumps should be rejected.

(4) Strength: The strength of cement can be roughly ascertained in the following ways:

- The briquettes with a lean or weak mortar are made. The size of briquette may be about 75 mm x 25 mm x 12 mm. The proportion of cement and sand may be 1:6. The briquettes are immersed in water for a period of 3 days. If cement is of sound quality, such briquettes will not be broken easily and it will be difficult to convert them into powder form.
- A block of cement 25 mm x 25 mm and 200 mm long is prepared and it is immersed for 7 days in water. It is then placed on supports 150 mm apart and it is loaded with a weight of 340 N. The block should not show signs of failure.
- A thick paste of cement with water is made on a piece of thick glass and it is kept under water for 24 hours. It should set and not crack.

12.3. Sand

The sand forms an important ingredient of mortar. The sand particles consist of small grains of silica (SiO_2). It is formed by the decomposition of sandstones due to various effects of weather. The sand is obtained from pits, rivers and seas.

(1) Pit sand: This sand is found as deposits in soil and it is obtained by forming pits into soils. It is excavated from a depth of about 1 m to 2 m from ground level. The Pit sand consists of sharp angular grains which are free from salts and it proves to be excellent material for mortar or concrete work. For making mortar, the clean pit sand free from organic matter and clay should only be used. When rubbed between the fingers, the fine pit sand should not leave any stain on the fingers. If there is any stain, it indicates the coating of oxide of iron over the sand grains.

(2) River sand: The sand is obtained from banks or beds of rivers. The river sand consists of fine rounded grains probably due to mutual attrition under the action of water current. The colour of river sand is almost white. As river sand is usually available in clean condition, it is widely used for all purposes.

(3) Sea sand: This sand is obtained from sea shores. The sea sand, like river sand, consists of fine rounded grains. The colour of sea sand is light brown. The salts contained in sand absorb moisture from the atmosphere. Such absorption causes dampness, efflorescence and disintegration of work. The sea sand also retards the setting action of cement. Due to all such reasons, it is the general rule to avoid the use of sea sand for engineering purposes except for filling of basement, etc. it can however be used as a local material after being thoroughly washed to remove the salt.

Properties of good sand:

Following are the properties of good sand:

- It should be chemically inert.
- It should be clean and coarse. It should be free from any organic or vegetable matter. Usually 3 to 4% clay is permitted.
- It should contain sharp, angular, coarse and durable grains.
- It should not contain salts which attract moisture from the atmosphere.
- It should be well graded i.e. should contain particles of various sieve and should not pass IS sieve No. 15. The fineness modulus of sand should be between 2 and 3.

Function of sand in mortar:

The sand is used in mortar and concrete for the following purposes:

- **Bulk:** It does not increase the strength of mortar. But it acts as adulterant. Hence the bulk or volume of mortar is increased which results in reduction of cost.
- **Setting:** if building material is fat lime, the carbon dioxide is absorbed through the voids of sand and setting of fat lime occurs effectively.
- **Shrinkage:** It helps in the adjustment of strength of mortar in the course of drying and hence the cracking of mortar during setting is avoided.
- **Strength:** It helps in the adjustment of strength of mortar or concrete by variation of its proportion with cement or lime. It also increases the resistance of mortar against crushing.
- **Surface area:** It subdivides the paste of the binding material into a thin film and thus more surface area is offered for its spreading and adhering.

The sand shall conform to the latest Indian Standard Institution Specifications No.IS.383-1963 with subsequent suppression and addition, if any. Sand for mortar and concrete shall be natural one collected from approved sand quarries, the maximum size of the particles being limited to 5 mm. The sand must be free from deleterious substances like clay, kankar and over size grains. The maximum percentages and deleterious substances in the sand as delivered for use on work shall not exceed 5% by weight. The sand shall be free from injurious amount of organic impurities and sand producing a

colour darker than the standard in the colorimetric test for organic impurities shall be rejected.

Tests for sand

Following tests may be carried out to ascertain the properties of sand:

- A glass of water is taken and some quantity of sand is placed in it. It is then vigorously shaken and allowed to settle. If clay is present in sand, its distinct layer is formed at top of sand.
- For detecting the presence of organic impurities in sand, the solution of sodium hydroxide or caustic soda is added to the sand and it is stirred. If colour of solution changes to brown, it indicates the presence of organic matter.
- The sand is actually tasted and from its taste, the presence of salts is known.
- The sand is taken from a heap and it is rubbed against the fingers. If fingers are stained, it indicates that the sand contains earthy matter.
- The colour of sand will indicate the purity of sand. The size and sharpness of grains may be examined by touching and by observing with eye.
- For knowing fineness, durability, void ratio, etc., the sand should be examined by the mechanical analysis.

12.4. Cement Mortar & Properties

The term mortar is used to indicate a paste prepared by adding required quantity of water to a mixture of binding like cement and fine aggregate like sand. The above two components of mortar, namely, the binding material and fine aggregate are sometimes referred to as the matrix and adulterant respectively. The matrix binds the particles of the adulterant and as such, the durability, quality and strength of mortar will mainly depend on the quantity and quality of the matrix. The combined effect of the two components of mortar is that the mass is able to bind the bricks or stones firmly.

The important properties of a good mortar mix are mobility, placeability and water retention. The term mobility is used to indicate the consistency of mortar mix which may range from stiff to fluid. The mobility of mortar mix depends on the composition of mortar and the mortar mixes to be used for masonry work, finishing work, etc. are made sufficiently mobile.

The placeability or the ease with which the mortar mix can be placed with minimum cost in a thin and uniform layer over the surface depends on the mobility of the mortar. The placeability of mortar mix should be such that a strong bond is developed with the surface of the bed.

A good mortar mix should possess the ability of retaining adequate humidity during transportation and lying over the porous bed. If water retention power of mortar mix is low, it separates into layers during transportation and when it comes into contact with porous bed such as brick, wood, etc., it gives away its water to that surface. Thus the mortar becomes poor in amount of water and the remaining water proves to be insufficient for its hardening. Hence the required strength of mortar will not be achieved with such a mortar mix.

12.5. Cement Concrete

The cement concrete is a mixture of cement, sand, pebbles or crushed rock and water, which, when placed in the skeleton of forms and allowed to cure, becomes hard like a stone. The cement concrete has attained the status of a major building material in all branches of modern construction because of the following reasons:

- It can be readily moulded into durable structural items of various sized and shapes at practically no considerable labour expenditure.
- It is possible to control the properties of cement concrete within a wide range by using appropriate ingredients and by applying special processing techniques – mechanical, chemical and physical.
- It is possible to mechanize completely its preparation and placing processes:
- It possesses adequate plasticity for the mechanical working.

In this chapter, the salient features of this important engineering material will be briefly discussed.

Properties of cement concrete

The Cement concrete possesses the following important Properties:

- It has a high compressive strength.
- It is free from corrosion and there is no appreciable effect of atmospheric agents on its.
- It hardens with age and the process of hardening continues for a long time after the concrete has attained sufficient strength. It is these properties of cement concrete which gives it a distinct place among the building materials.
- It is proved to be more economical than steel. This is due to the fact that sand and pebbles or crushed rock, forming the bulk of cement concrete, to the extent of about 80 to 90% are usually available at moderate cost. The formwork, which is of steel or timber, can be used over and over again or for other purposes after it is removed.
- It binds rapidly with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete at suitable places to take up the tensile stresses. This is termed as the Reinforced Cement Concrete or simply R.C.C
- Under the following conditions, it has a tendency to shrink:
 - (i) There is initial shrinkage of cement concrete which is mainly due to the loss of water through forms, absorption by surfaces of forms, etc.
 - (ii) The shrinkage of cement concrete occurs as it hardens. This tendency of cement concrete can be minimized by proper curing of concrete.
- It has a tendency to be porous. This is due to the presence of voids which are formed during and after its placing. The two precautions necessary to avoid this tendency are as follows:
 - (i) There should be proper girding and consolidating of the aggregates.
 - (ii) The minimum water –cement ratio should be adopted.
- It forms a hard surface, capable of resisting abrasion.
- It should be remembered that apart from other materials, the concrete comes to the site in the form of raw materials only. Its final strength and quality depend entirely on local conditions and persons handling it. However the materials of which concrete is composed may be subjected to rigid specifications.

12.6. Materials used in R.C.C. work

Cement, Aggregates, Steel and Water are four materials required for making R.C.C.

(1) Cement: Most of the cement concrete work in building construction is done with ordinary Portland cement at present. But other special varieties of cement such as rapid hardening cement and high alumina cement are used under certain circumstances. The cement should comply with all the standard requirements.

(2) Aggregates: These are the inert or chemically inactive materials which form the bulk of cement concrete. These aggregates are bound together by means of cement. The aggregates are classified into two categories: fine and coarse.

The material which is passed through IS test sieve no. 480 is termed as fine aggregate. Usually, the natural river sand is used as a fine aggregate. But at places, where natural sand is not available economically, the finely crushed stone may be used as a fine aggregate.

The material which is retained on IS test sieve no. 480 is termed as a coarse aggregate. The broken stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. For thin slabs and walls, the maximum size of coarse aggregate should be limited to one-third the thickness of the concrete section.

The aggregates to be used for cement concrete work would be hard, durable and clean. The aggregates should be completely free from lumps of clay, organic and vegetable matter, fine dust, etc. The presence of all such debris prevents adhesion of aggregates and hence reduces the strength of concrete.

All aggregates shall conform to either IS: 383-1963 or IS: 515-1959 with subsequent suppression or addition, if any. For heavily reinforced concrete members as in the case of ribs of main beams, the nominal maximum size of the aggregate should usually be restricted to 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum cover to the reinforcement, whichever is smaller.

For reinforced concrete work aggregates having a maximum size of 20 mm are generally considered satisfactory and this requirement shall be strictly adhered to.

(3) Steel: The steel reinforcement is generally in the form of round bars of mild steel. The diameters of bars vary from 5 mm to 40 mm. sometimes the square bars or twisted bars or ribbed-rod steel are used as steel reinforcement. For road slabs and such other construction, the reinforcement may also consist of sheets of rolled steel of suitable thickness.

(4) Water: This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc. In general, the water which is fit for drinking should be used making concrete. Water for use in masonry, concrete, mortar, washing and curing shall conform to IS 456-2000 with subsequent suppression and addition if any, be clean and free from objectionable quantities or silt, organic matter, alkali, salts, oil and other impurities which are likely to be injurious.

5) Other Ingredients: It may be noted that sometimes the ingredients other than above are added in concrete to give it certain improved qualities or for changing different physical properties in its fresh and hardened stages. These ingredients or substances are known as admixtures. The addition of an admixture may improve the concrete with respect to its strength, hardness, workability, water resisting power, etc.

Following are the commonly used admixtures:

Alum, aluminum sulphate, barium oxide, bitumen, calcium chloride, coal ash, common salt, iron oxide, lime, mineral oils, organic oils, potassium chloride, silicate of soda, tar products, volcanic ashes, zinc chromate, etc.

For instance, when calcium chloride (CaCl_2) is added as admixture, it absorbs water from the concrete and water-cement ratio falls down and can even be brought down up to the

limit of 0.25. Thus it gives quick setting concrete. However the use of limit of chloride is not suitable for concrete with reinforcing bars.

Depending upon their respective activities in the concrete mix, the admixtures can be classified in the following five categories:

- Accelerators,
- Air entraining admixtures,
- High range of water reducers or super plasticizers,
- Normal range of water reducers or plasticizers and
- Retarders.

It may be noted that some admixtures may have the combined effect of the above individual activities. The popularity of various types of admixtures in concrete is increasing rapidly because of the following advantages available from their use:

- adjusting the final setting times of concrete,
- higher early and ultimate strengths,
- higher slump and self-leveling concrete,
- increasing durability of concrete,
- lesser water-cement ratios,
- reducing quantity of cement,
- reduction in the permeability of concrete,
- Time savings in terms of repair and maintenance, etc.

12.7. Water-cement ratio

The water in concrete has to perform the following two functions.

- The water enters into chemical action with cement and this action cause the setting and hardening of concrete.
- The water lubricates the aggregates and it facilitates the passage of cement through voids of aggregates. This means that water makes the concrete workable.

It is found theoretically that water required for these two functions is about 0.50 to 0.60 times the weight of cement. This ratio of the amount of water to the amount of cement by weight is termed as the water-cement ratio and the strength and quality of concrete primarily depend upon this ratio. The quantity of water is usually expressed in liters per bag of cement

Points to be observed in connection with the water-cement ratio are as follows:

- The minimum quantity of water should be used to have reasonable degree of workability. The excess water occupies space in concrete and on evaporation, voids are created in concrete. Thus the excess water affects considerably the strength and durability of concrete. In general, it may be Stated that addition of one extra litre of water to the concrete of one bag of cement will reduce its strength by about 1.47 N/Sq.mm. In other words, the strength of concrete is inversely proportional to the water-cement ratio.
- The water-cement ratio for structures which are exposed to weather should be carefully decided. For structures which are continuously under water, the water cement ratio by weight should be 0.55 and 0.65 for thin sections and mass concrete respectively.
- Some rules-of thumb are developed for deciding the quantity of water in concrete. The *two* such rules are mentioned below. The rules are for ordinary concrete and they assume that the material is non-absorbent and dry.

(i) Weight of water = 28% of the weight of the cement + 4% of the weight of total

aggregate.

- (ii) Weight of water = 30% of the weight of total aggregate +5% of the weight of total aggregate.

Compressive strengths for various Water –Cement ratios (table 12.1)

TABLE 12.1

Net Water-Cement ratio by weight	Probable cube crushing Strength in N/Sq.mm	
	7 Days	28 Days
0.35	40	52.5
0.40	35	47
0.45	30	42
0.50	25	37
0.55	22	33
0.60	18	28
0.65	15.5	24.5
0.70	13.5	22
0.75	11.2	20
0.80	10.5	17.5

12.8. Workability:

The term workability is used to describe the ease or difficulty with which the concrete is handled, transported and placed between the forms with minimum loss of homogeneity. However, this gives a very loose description of this vital property of concrete which also depends on the means of compaction available. For instance, the workability suitable for mass concrete is not necessarily sufficient for thin, inaccessible or heavily reinforced sections. The compaction is achieved either by ramming or by vibrating. The workability, as a physical property of concrete alone irrespective of a particular type of construction, can be defined as the amount of useful internal work necessary to produce full compaction. If the concrete mixture is too wet, the coarse aggregates settle at the bottom of concrete mass and the resulting concrete becoming of non-uniform composition. On the other hand, if the concrete mixture is too dry, it will be difficulty to handle and place it in position. Both these conflicting conditions should be correlated by proportioning carefully various components of concreted mixture. The important facts in connection with workability are as follows:

- If more water is added to attain the required degree of workmanship, it results into concrete of low strength and poor durability.
- If the strength is not to be affected, the degree of workability can be obtained by slightly changing the proportions of fine and coarse aggregates, in case the concrete mixture is too wet; and by adding a small quantity of water cement paste in the proportion of original mix, in case the concrete mixture is too dry.
- A concrete mixture of one work may prove to be too stiff or too wet for another work. For instance, the stiff concrete mixture will be required in case of vibrated concrete work while wet concrete mixture will be required for thin sections containing reinforcing bars.
- The workability of concrete is affected mainly by water content, water-cement ratio and aggregate-cement ratio.
- The workability of concrete is also affected by the grading, shape, texture and maximum size of the coarse aggregates to be used in the mixture.

In order to measure the workability of concrete mixture, the various tests are developed. The tests such as flow test and compacting test are used in great extent in laboratory. The slump test, which is commonly used in the field, is briefly described below.

Slump test

The standard slump cone is placed on the ground. The operator holds the cone firmly by standing on the foot pieces. The cone is filled with about one-fourth portion and then rammed with a rod which is provided with bullet nose at the lower end. The diameter of the rod is 16 mm and its length is 60 mm. The strokes to be given for ramming vary from 20 to 30. The remaining portion of the cone is filled in with similar layers and then the top of concrete surface is struck off so that the cone is completely full of concrete. The cone is then gradually raised vertically and removed. The concrete is allowed to subside and then the height of concrete is measured. The slump of concrete is obtained by deducting height of concrete after subsidence from 30 cm.

Recommended Slumps of Concrete (table 12.2)

TABLE 12.2

S.No	Type of Concrete	Slump
1.	Concrete for tops of curbs, parapets, piers, slabs, and walls that are horizontal	40 to 50 mm
2.	Normal R.C.C. work	80 to 150 mm
3.	Mass concrete	25 to 50 mm
4.	Concrete to be vibrated	10 to 25 mm

The concrete shall conform to IS: 456-2000 and IS: 3370. The coarse aggregate and fine aggregate for the concrete shall be the hardest, cleanest and most durable material available from approved quarries and shall be free from all deleterious matter, such as dust, lumps of clay, soft and flaky pieces, shale, alkali, organic matter, loam etc.,

Characteristic Strength of 150 mm cubes at the end of 28 days (table 12.3)

TABLE 12.3

Concrete Grade	Compressive Strength
M-10	10 N/Sq.mm
M-15	15 N/Sq.mm
M-20	20 N/Sq.mm
M-25	25 N/Sq.mm

12.9. Nominal Mix Concrete

Wherever directed or as per drawing nominal mix concrete may be used for concrete of grades M10, M15, M 20 In proportioning concrete, the quantity of cement should be determined by weight. The quantity of fine and coarse aggregates may be determined by volume, but these should also preferably be determined by weight. In the latter case the weight should be determined from the volume specified in Table II and the weight per litre of dry aggregate. If fine aggregate is moist, the volume batching is adopted, and Allowance shall be made for bulking in accordance with IS: (Part-III) – 1963.

12.10. Consolidation

The main aim of consolidation of concrete is to eliminate air bubbles and thus to give maximum density to the concrete. An intimate contact between concrete and reinforcement is ensured by proper consolidation. The importance of consolidation of concrete can be seen from the fact that a presence of 5% of voids reduces 30% strength of concrete. The difference between voids and pores may be noted. The voids are the gaps between two individual particles. The pores represent the openings within the individual particles. The process of consolidation of concrete can be carried out either with hand or with the help of vibrators.

1) Hand consolidation

For unimportant works, the consolidation of concrete is carried out by hand methods which include ramming, tamping, spading and slicing with suitable tools. The hand methods require use of a fairly wet concrete. It should however be remembered that wherever feasible, the hand compaction should be preferred because the use of vibrator may lead to the segregation of the aggregates. As a matter of fact, the concrete mixes which can be hand-compacted should not be compacted by the use of vibrators.

2) Vibrators

These are the mechanical devices which are used to hand methods are

- It is possible by means of vibrators to make a harsh and stiff concrete mix, with a slump of about 40 mm or less, workable.
- The quality of concrete can be improved by use of vibrators as less water will be required or in other way, economy can be achieved by adopting a leaner mix when vibrator are used.
- The use of vibrators results in the reduction of consolidation time. Hence the vibrators are used where the rapid progress of work is of great importance.
- With the help of vibrators, it is possible to deposit concrete in small openings or places where it will be difficult to deposit concrete by hand methods.

12.11. Curing of concrete

The concrete surface is kept wet for a certain period after placing of concrete, so as to promote the hardening of cement. It is controlling of temperature and of the moisture movement from and into the concrete. The term curing of concrete is used to indicate all such procedures and processes.

Following are the objects or purposes of the curing of concrete:

- The curing protects the concrete surfaces from sun and wind.
- The presence of water is essential to cause the chemical action which accompanies the setting of concrete, normally; there is an adequate quantity of water at the time of mixing to cause hardening of concrete. But it is necessary to retain water until the concrete has fully hardened.
- The strength of concrete gradually increases with age, if curing is efficient. This increase in strength is sudden and rapid in early stages and continues slowly for an indefinite period.

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- By proper curing, the durability and impermeability of concrete are increased and shrinkage is reduced.
 - The resistance of concrete to abrasion is considerably increased by proper curing.

Period of curing

This depends on the type of cement and nature of work. For ordinary Portland cement. The curing period is about 14 to 21 days. If rapid hardening cement is used, the curing period can be considerably reduced.

Effects of improper curing

- The chances of ingress of chlorides and atmospheric chemicals are very high.
- The compressive and flexural strengths are lowered.
- The cracks are formed due to plastic shrinkage, drying shrinkage and thermal effects.
- The durability decreases due to higher permeability.
- The frost and weathering resistances are decreased.
- The rate of carbonation increases.
- The surfaces are coated with sand and dust and it leads to lower the abrasion resistance.

The above disadvantages are more prominent in those parts of structures which are either directly exposed or those which have large surfaces compared to depth such as roads, canals, bridges, cooling towers, chimneys, etc. It is therefore necessary to protect the large exposed surfaces even before setting, otherwise it may lead to a pattern of fine cracks.

Factors affecting evaporation of water from concrete: Following are the four basic factors on which the evaporation of water from the concrete surface depends:

- air temperature;
- fresh concrete temperature;
- relative humidity; and
- Wind velocity.

12.12. Reinforcement

- Mild steel and medium tensile steel bars and hard-drawn steel wire conforming to IS:432-1960
- Deformed bars conforming to IS: 1139-1959.
- Cold twisted steel bars conforming to IS: 1786-1961 with yield strength of 4250 Kg/sq.cm.
- Hard-drawn steel wire fabric conforming to IS: 1566-1960 and
- Structural steel sections conforming to IS-226-1962

Reinforcement shall conform in shape and position to details indicated on RCC drawings, hooks shall conform to the requirement of IS-456-2000. Steel supplied should bear the Manufacturer's test certificate for its quality as per relevant IS 432 Part I, IS 439, IS 1786. For all RCC works Fe 415.

Laboratory tests

The minimum tests to be done and the acceptable limits are indicated in table 12.4.

TABLE 12.4

S.No	Property	MS GR.II (IS 432) N/Sq.mm	MS GR I (IS 432) N/Sq.mm	Fe 415 (IS 1786) N/Sq.mm	Fe500 (IS 1786) N/Sq.mm
1.	0.2% of Yield Stress	415	500
2.	Ultimate Tensile Strength	370	410	485	540
3.	Percentage of elongation minimum	23%	23%	14.5%	8%

NOTE: In general Fe 415 rods are used for the works.

Other tests

In addition to the above tests, average diameter (or area of cross section) and weight per unit length are also to be tested as follows:

Size in mm	Area in Sq.cm	Weight in Kg/m
8	0.50	0.367 - 0.423
10	0.78	0.574 - 0.660
12	1.13	0.844 - 0.932
16	2.01	1.500 - 1.660
20	3.14	2.400 - 2.500
22	3.80	2.891 - 3.069

Note: For the purpose of checking the nominal mass or the density of steel shall be taken as 0.00785 Kg/Sq.mm of the cross sectional area per metre run.

12.13. Hand Pumps

Standard Specifications:-The pipes, fittings and other components should be as per Indian Standard Specifications and should be obtained from approved vendors. Proper arrangements for storage of material should be made at stores as well as the sites. As far as possible, the entire material required for a particular site should be procured and transported at one time, to avoid loss of time. Proper check should be adopted in using the materials at site. If any material is found defective or is of inferior quality it should be removed and kept separately to avoid inter-mixing with good material. The pipes, strainers and connecting rods do not have any cracks or undesirable dents. The threaded end of GI pipes and connected rods are intact and are in good condition. Each and every pipe must be fitted with HDPE cap at one end and with a socket at the other end.

Performance: - Performance Characteristic of Hand Pumps are shown in table 12.5.

TABLE 12.5

Characteristics	Indian Mark II	Indian Mark III (65mm)	Indian Mark III (65mm)	Extra Deep well
Minimum Bore well diameter	100	125	100	100
Application Range				
a. Statistic Water Level (M)	15-40	15-25	15-50	40-90
b. Optimum installation depth (M)	21-40	21-30	21-60	50-90
Stroke length	125	125	125	100
Discharge/40 stroke/litters/minutes	15	15	10	12
Riser Main				
a. Size (mm)	32	65	50	32
b. Material	GI	GI	GI	GI
Connecting Rod				
a. Size (mm)	12 Steel	12 Steel	12 Steel	12 Steel
b. Material	Zinc Plated	Zinc Plated	Zinc Plated	Zinc Plated
National/International Standards	IS:9301	IS:13056 & RUWA TSANI NIS-325	IS:13056	IS:13287

Materials required for India Mark II/III Hand Pump should be relevant to IS Codes given in table 12.6.

TABLE 12.6

Hand Pump details	Relevant IS: Code
India Mark deep well hand pump	IS 9301:1990
India Mark III Deep well	IS 13506:1991
UPVC pipe 6kg/Sq.m	
140mm/110mm diameter	IS 4985:1981
63 mm diameter	IS 4985:1981
GI Pipe (Riser Pipe)	
32 mm diameter (medium)	IS 1239 Part I: 1979
65 mm diameter (medium)	IS 1239 Part I: 1979
Miscellaneous	
UPVC ribbed strainer	IS 12818:1989
63 mm diameter slot size – 0.2mm	
Installation	IS 11004 (Part I) 1985
Packing & Storing	IS 12732:1989

Packing and storing

Ensure that materials received in the stores are duly stamped by the authorized inspecting agents and are properly packed. Unless otherwise specified in the contract or order, packing should be as follows:

- The cylinders should be packed in wooden cases and the net weight of each should not exceed 50 kg.
- The pump head assembly should normally be wrapped in paper or open-ended polyethylene bags and straw/wood wool to withstand road transit.
- The connecting rods should be packed in bundles of 10. Each bundle should be wrapped in open-ended polyethylene bags and then with two layers of Hessian cloth.
- The riser pipe (32mm or 65mm dia, GI of medium quality) should be packed as per IS 4740:1979.

Testing

Materials received in the stores should be tested before use. Testing should be done in the manner specified below.

1. Sampling

Unless otherwise specified in the contract/order, the procedures given in IS: 2500 (Part-I) 1975 should be adhered to.

In general sampling is done by randomly drawing part of the material from the lot, which is considered to be representative of the entire lot.

2. Type Test

Performance of the pump should be checked, by placing the pump cylinder in a barrel of 200 litres water capacity. The barrel should be fed with water at the rate of 20 lit/min by means of suitable arrangements. The pump should be primed and the test should start only after getting continuous flow of water through the spout. The water should then be collected in a container for 40 continuous strokes to be completed in one minute and the discharge thus measured shall not be less than 15 liters (IS 9301:1990 and IS 13056:199).

3. Visual and dimensional Tests

- All the pumps should be examined for finish and visual defects.
- All the dimensions of the assemblies should be checked and confirmed that they are as per IS specification.
- The handle should have reasonably good surface contact with the bracket.
- Riser pipe holder shall be checked for verticality. The maximum allowable tilt is 1mm for a 300mm long plain mandrel screwed to the coupling holder.
- The flanges should be reasonably flat to provide proper matching.
- The strokes of the pump should be 120 in 3 minutes
- Connecting rod and plunger rod should be examined for straightness and formation threads. The hexagonal coupled should also be subjected to similar checks.
- Pump head and cylinder should be marked with the manufacturer name, trademark, batch number and serial number.
- The chain should be smeared with graphite grease prior to dispatch.
- One hexagonal nut should be attached to chain coupling to be used for locking the last connecting rod to chain coupling.
- Assembly should be checked for alignment of rod with respect to guide bush.

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- The lateral play at the end of square section of the handle should exceed 2 mm on either side.
 - The clearance between handle and bracket should not be less than 1.5 mm
 - Check valve and plunger valve should move feely after assembly.
 - The cylinder assembly should be checked for leakage of water

12.14. Jet Pump

Motor

The motor should conform to IS 7538/1975 and as amended from time to time and bear ISI marking. Motor should be suitable for operation between 300 and 440 volts. The motor winding should be suitable for DOL starter upto 5 HP and star/delta starter above 5 HP. The insulation should be of class B and suitable for operation as 3 phase. 300 to 440 volts, 50 cycles A.C. supply.

Pump

The pumps should conform to IS 12225/1987 and as amended from time to time with ISI marking. For other items without ISI marking the pump should conform to IS 6595/1980 and as amended from time to time for construction features. The pumps should be compact monoblock without power transmission losses for horizontal mounting. Speed of motor and pump shall be in the range of 2700 to 2800 RPM.

Inspection and Testing

Inspection and testing of various components of pump sets as well as testing of complete pump set after assembly will be done by the engineers deputed. The result achieved during testing should tally with the data/specification furnished by the Supplier in the tender/Agreement.

The guidelines for the inspection procedure will be as follows:

- i) Manufacturer should submit test certificate on the casting for physical and chemical properties for each and every pump set. The inspecting authority on their discretion may take samples of raw materials of casting for due verification of the composition and ascertain whether the materials supplied conform to the relevant standard.
- ii) Dynamic balancing certificate for the impellers and the result should be submitted for verification.
- iii) Manufacturer should test each and every pump set for hydraulic performance and submit the result for verification.
- iv) Manufacturer should carry out no load test for each and every motor and full load test for every 5 motors and temperature rise for every 20 motors and submit the result for verification.
- v) The inspection authority will see the performance of motor, type of tests of motors, including temperature rise test, torque test, hydraulic performance test and dynamic balancing on random samples. Necessary facilities also be provided to inspecting authority for checking every individual component of the pump set.
- vi) All the pump sets which are approved for delivery by the inspecting authority shall bear the inspection marking as stipulated in general forms and conditions of contract.
- vii) The pump test should be done taking into consideration of pipe friction losses using orifice plate.

12.15. Submersible Pump

The submersible pump-set should conform to I.S 8034-1989 with latest amendment. The pump should be fitted dynamically balance enclosed type impeller. Each impeller shall be balanced dynamically to grade of G 6.3 (6.3mm/s). The pump shaft shall be guided by bearing provided in each stage bowl & in the suction and discharge casing. The inlet passage of the suction casing shall be stream lined to avoid eddies. The suction case shall be fitted with a strainer of corrosion resistant material. Suitable sand guard shall be provided just above the suction case bearing to prevent the entry of foreign material into suction case. The pump should be provided with the non return valve above the pump discharge case with standard flanged connection. The individual casting part or pump as a whole in assembled condition should be able to withstand a hydrostatic pressure of 1.5 times maximum discharge pressure. The gaskets & seals used shall conform to I.S 5120-1968 or latest. The cable clamp of adequate size be supplied for fixing submersible cables to the rising main pipes.

The pump shall be directly coupled to a submersible motor. The submersible motor shall be squirrel cage induction motor conforming to I.S 9283-1979 or latest capable of operating on 415+ 6% volts, 3 phase 50 cycles. A.C. supply both pump and motor shall run at 2900 R.P.M. the water lubricated thrust bearing should be of adequate size to withstand the weight of all rotating parts as well as the imposed hydraulic thrust. The motor shall be protected by means of cable glands, rubber seals etc from ingress of bore well water, sand and other foreign material. The motor shall be provided with breathing attachment like bellows, diaphragm etc. to compensate the volumetric variation due to change in the temperature. The motor shall be made of corrosion resisting material or suitable materials to resist corrosion under normal conditions. The rotor shall be provided with shaft protecting sleeves having a surface finish of 0.75 microns Ra Max. the starter shall be star delta. The class of insulation shall be F. the submersible cable of L&T & finolex make for submersible motor shall conform to IS 694 (Part-III)-1964 or latest. The flanged column pipe shall conform table 2 I.S 1239 (Part-1) 1979 or latest (Medium Class) Table – 2.

The efficiency of submersible pump shall be guaranteed to specified point of rating only & shall not be guaranteed to cover the performance of the pump under condition varying there from nor for a sustained performance for any period of time. The pump discharge may be guaranteed for the range of head between – 25% & +10% of the specified head when the latter is 30 meters or above. Below 30 meters the limits shall be from 25% to 25% or +3 meters whichever is less. The H.P of motor shall be such that it shall be 15% in excess of maximum H.P required under all heads of working. Performance guarantees shall be based on laboratory tests corrected for field performance.

12.16. Horizontal Centrifugal Pump

The specification covers the design, performance, manufacturing, shop testing, and erection, testing and commissioning at site of the horizontal centrifugal pumps.

Codes and Standards

The design, manufacture and performance of the horizontal centrifugal pumps shall conform to the latest revisions of the following codes and Indian Standards, in addition to other stipulations and standards mentioned elsewhere in the specification.

Pump Characteristics

Consistent with good operating characteristics and high efficiency, each pump shall have a continuously rising head capacity characteristics curve without any zone of instability. Power flow characteristic shall preferably be non-overloading type. Beyond rated duty point. The characteristic curves of each set of pumps shall match each other for equal sharing in case of parallel operation. The pump motor set shall be designed in such a way that there is no damage due to reverse flow through the pump which may occur due to any mal operation of the system. The pumps shall be suitably designed for smooth and trouble free continuous solo operation even in the event to trip out, the remaining pumps run in parallel. The pumps shall be designed to have best efficiency at the rated duty point. The pumps shall be suitable for continuous operation within a wide range above and below the rated duty point. The vendor shall clearly indicate in his offer, such range of operation within which each category of pumps can satisfactorily operate on continuous basis.

Drive motors from each category of pumps shall be suitable for use on 414 V + 10% 3 phase. 50 Hz. + and neutral grounded system. Drive motors shall have 15% spare margin over the maximum power requirements of the pump within the range of operation.

Testing and Inspection at Manufacturer's Work site

The manufacturer shall conduct all tests required to ensure that the equipment furnished shall conform to the requirements of this specification and in compliance with requirements of the applicable codes. The Buyer's (GP) representatives shall be given full access to all tests. Prior to pump performance tests, the Manufacturer shall inform the Buyer allowing adequate time so that if the Buyer desires his representatives can witness the test. All materials and casting used for the equipment shall be to tested quality. The test certificates shall be made available to buyer. The pump casing shall be hydraulically tested at 200% of pump rated head or at 150% of shut-off head, whichever is higher. The test pressure shall be maintained for at least half an hour. The pump rotating parts shall be subjected to static and dynamic balancing tests. All pumps shall be tested at the shop for capacity, head efficiency and brake horsepower and cavitations. The tests are to be done according to the requirements of the "Hydraulic Institute" of U.S.A., ASME Power Test Code PTC-8.2 (latest edition) and Indian Standards as applicable. The pumps accessories e.g. the thrust bearing, the motor pump shaft coupling etc. will be subjected to tests as per Manufacturer's standard. The combined vibration of pump and motor should be restricted to the limits specified by Hydraulic Institute Standard, USA, when the pump in operation at any loads singly or in parallel. Tests on motors shall be conducted as per electrical specification enclosing herewith this specification. The reports and certificates of all the above-mentioned tests to ensure satisfactory operation of the system shall be submitted to the buyer before dispatch. Cast heat marks to be provided on castings for casing and impeller.

Tests at Site

After erection at site, pumps as detailed under different groups shall be operated to prove satisfactory performance as individual equipment as well as a whole system for the water supply scheme.

12.17. Vertical Centrifugal Pump

The specification covers the design, performance, manufacturing, shops testing, erection, testing and commissioning at site of the vertical centrifugal pumps.

Codes & Standards:-The design, manufacture and performance of the vertical centrifugal pumps shall conform to the latest revisions of the following code and Indian Standard in addition to other stipulations and standards mentioned elsewhere in the specification.

IS: 1710 Vertical Turbine Pumps for clear, cold, fresh, water.

Pump Characteristics:-Head capacity curve should be rising up to the shut-off head condition. Power versus capacity curve shall be non-overloading type beyond rated duty point. The characteristic curves of each set of pumps shall match each other for equal load sharing in case of parallel operation. The pump shall however, be also designed for smooth and trouble-free continuous solo operation in the event of trip-out of the remaining pumps running in parallel. The pumps shall be designed for reverse flow through them. The drive motor shall be capable of bringing the pump to its rated speed in the normal direction from the point of maximum possible reverse speed when power to the drive is restored. The pumps shall be designed to have best efficiency at the rated duty point. The pumps shall be suitable for continuous operation with a wide range above and below the rated duty point. The Vendor shall clearly indicate in his offer, such range of operation within which the pumps can satisfactorily operate on continuous basis. Drive motors for the pumps shall be suitable for use on 415v + 10%, 3 phase 50 HZ + 5% and neutral grounded system. Drive motors shall have 15% spare margin over the maximum power requirement of the pump within its range of operation.

Tests at Site

After erection at site, pumps as detailed under different groups shall be operated to prove satisfactory performance as individual equipment as well as a system.

12.18. Vertical turbine Pumps

These are also called Dynamic pressure pumps and are used for deep wells that is more than 150 m. This is a multistage pump with vertical spindles. These pumps are capable of discharging 300 to 52000 litres/minute.

Electric Motors Up to 415 V

Following are the specifications of the squirrel cage induction motors. Motor shall conform in all respect to following specifications and specific requirements of rating, voltage, speed, mounting, type of enclosure, area classification, gas groups, and cable size mentioned herein. Motors shall conform to relevant Indian Standards, some of which are listed in table 12.7 with up to date revisions.

TABLE 12.7

Sr.No.	Code	Parts
1.	IS-325	Induction motors, 3 phase
2.	IS-1231	Induction motors, three phase foot mounted, dimensions of
3.	IS-4029	Induction motors, three phase guide for testing
4.	IS-2223	Flange mounted AC induction motors, dimensions of
5.	IS-2253	Designations for types of construction and mounting arrangements of rotating electrical machines
6.	IS-4691	Degrees of protection provided by enclosures for rotating electrical machinery
7.	IS-4889	Rotating electrical machines, efficiency of methods of determination
8.	IS-4729	Measurement and evaluation of vibration of rotating electrical machines
9.	IS-4728	Terminal marking for rotating electrical machinery.

Power Supply:

Voltage 400/415 volts

No. of Phases 3

Frequency 50 c/s

Neutral Solidly grounded

Approximate duration of fault for considering short circuit withstand of motor may be assumed 0.25 sec.

12.19. PVC Insulated Electric cables**Power Cable**

650/1100 volts grade, PVC insulated, extruded PVC inner sheathed, flat/round galvanized steel wire armored overall PVC served, aluminium conductor cable conforming to IS:1554 (Part I) with its latest amendments and of required sizes and lengths shall only be used for the work in this project.

Control Cable

650/1100 Volts, PVC, insulated, extruded, PVC inner sheathed, round galvanized steel wire armored overall PVC served, copper conductor cable conforming to IS:1554 (Part I) with its latest amendments and of required lengths shall only be used for the work under this project.

12.20. Cast Iron Pipes

Cast Iron flanged pipes and fittings are usually cast in the larger diameters. Smaller sizes have loose flanges screwed on the ends of double spigot-spun pipe. The method of Cast Iron pipe production used universally today is to form pipes by spinning or centrifugal action. Compared with vertical casting in sand moulds, the spun process results in faster production, longer pipes with vastly improved metal qualities, smoother inner surface and reduced thickness and consequent lightweight. All C.I. Pipes and specials supplied shall confirm to I.S. 1536-1976.

Specification For vertically Cast (Spun) Iron pressure pipes for Water, Gas and Sewage are as per IS 1537-1976 and Specification for Cast Iron Fittings for Pressure pipes are as per I.S. 1538 – 1976 (Part V)

Centrifugally cast iron pipes are available in diameters from 80 mm to 1050 mm and are covered with protective coatings. Pipes are supplied in 3.66m and 5.5m lengths and a variety of joints are available including socket and spigot and flanged joints.

The pipes have been classified as LA, A and B according to their thicknesses. Class LA pipes have been taken as the basis for evolving the series of pipes. Class A allows a 10% increase in thickness over class LA. Class B allows a 20% increase in thickness over class LA. The pipes are spigot and socket type. The test pressure as and working pressure are as per table 12.8.

TABLE 12.8

SNo	Class of Pipe	Test Pressure in Kg/sq cm	Working Pressure in Kg/sq cm
1	Class LA	35	10
2	Class A	35	12.5
3	Class B	35	16

Hydraulic test pressures for vertically cast iron pipes as per IS 1537 (table 12.9)

TABLE 12.9

Nominal Dia	Test pressure in kg/cm ²			
	Socket & spigot pipes		Flanged pipes	
	Class A	Class B	Class A	Class B
Upto & including 300 mm	20	25	20	25
Over 300 mm upto 600 mm	20	25	15	20
Over 600 mm upto 1000 mm	15	20	10	15
Over 1000 mm upto 1500 mm	10	15	10	10

Note: Max. working pressure not less than 2/3 of test pressure.

Cast Iron Fittings for Pressure Pipes

Ref: IS-1538 – Part I to XXIII – 1976 (Third Reprint-1986) Second Revision

The major piping materials are produced also in the form of standard fittings. Cast iron fitting are made by conventional founding method for a variety of joints including double socket, socket and spigot, double flanged, flanged and socketted, flanged and spigotted and mechanical (gland type) designs.

Hydraulic Test: For hydraulic tests, the fitting shall be kept under pressure for 15 seconds. The fittings shall withstand pressure as indicated in table 12.10 without showing any leakage or sweating or any other defect of any kind.

Hydraulic Test pressure for fittings as per IS – 1538-Third print 1986 (table 12.10)

TABLE 12.10

Nominal Dia	Test pressure in Kg/Sq.cm	
	Fitting without branches or with branches not greater than half the principal diameter	Fitting with branches greater than half of the principal diameter.
Upto & including 300 mm	25	25
Over 300 mm and upto and including 600 mm	20	20
Over 600 mm and upto and including 1800 mm	15	10

Weight: The standard weights of the specials are shown in the respective tables of IS Code. The permissible tolerance in standard weights shall be $\pm 8\%$ except for bend fittings with more than one branch and non-standard fittings, in which case the tolerance shall be $\pm 12\%$.

Coating: Except when otherwise agreed, all fittings shall be coated externally and internally.

Joints: Several types of joints such as rubber gasket joint known as Tyton joint, mechanical joint known as Screw Gland joint, and conventional joint known as Lead joint are used. Joints are classified into the following three categories depending upon their capacity for movement. (IS 1538-1976)

- (a) Rigid Joints
- (b) Semi Rigid Joints
- (c) Flexible Joints:

12.21. Steel Pipes

Steel pipes of smaller diameter can be made from solid bar section by hot or cold drawing processes and these tubes are referred to as seamless, as per IS 1239.

But the larger sizes are made by welding together the edges of suitably curved plates, the sockets being formed later in a press (IS: 3589). Specials of all kinds can be fabricated without difficulty to suit the different site conditions. Due to their elasticity, steel pipes adopt themselves to changes in relative ground level without failure and hence are very suitable for laying in ground liable to subsidence. If the pipes are joined by a form of flexible joint (IS-554), it provides an additional safeguard against failure. Steel pipes being flexible are best suited for high dynamic loading.

Hydraulic Test: For hydraulic tests, the fitting shall be kept under pressure for 15 seconds. The fittings shall withstand pressure as indicated in IS code without showing any leakage or sweating or any other defect of any kind. Each tube shall be hydraulically tested at manufacturer's site to withstand a test pressure of 5 MPa. The Permissible working pressure for mild steel tubes are shown in table 12.11.

TABLE 12.11

Permissible working pressure for mild steel tubes

Nominal Bore of pipe in mm	Working pressure in kg/cm ²	
	Medium	Heavy
50	14.06	17.58
65	14.06	17.58
80	14.06	17.58
100	12.02	16.03
125	12.02	14.79
150	9.98	12.02

12.22. Ductile Iron Pipes

Ductile iron pipes are normally prepared using the centrifugal cast process. The ductile iron pipes are usually provided with cement mortar lining at the factory by centrifugal process to ensure a uniform thickness through out its length. Cement mortar lining is superior to bituminous lining as the former provides a smooth surface and prevents tuberculation by creating a high pH at the pipe wall and ultimately by providing a physical and chemical barrier to the water.

The Indian standard IS 8329-1994 provides specifications for the centrifugally cast ductile iron pipes (Similar to ISO: 2531-1998 and EN: 545-1994). These pipes are available in the range of 80mm to 1000 mm diameter; in length of 5.5 to 6m. These pipes are being manufactured in the country with ISO 9002 accreditation.

Ductile iron pipes are lined with cement mortar in the factory by centrifugal process and unlined ductile iron pipes are also available. For more details reference may be made to IS 8329-1994 for Ductile Iron pipes.

The ductile iron fittings are manufactured conforming to IS 9523-1980. The joints for ductile iron pipes are suitable for use of rubber-gaskets conforming to IS 5383. The tensile strength and hydraulic test pressure for D>I pipes are shown in table 12.12 & 12.13 respectively.

TABLE 12.12

Tensile Strength of D.I pipe

Nominal Dia in mm	Max. Tensile Strength in MPa	Min. elongation at break (%)
80-1000	420	10
1100-2000	420	7

TABLE 12.13

Hydraulic test pressure for D.I pipes

Nominal dia in mm	D.I pipes with flexible joints			Pipes with screwed or welded flanges			
	Class K ₇	Class K ₈	Class K ₉ Class K ₁₀ Class K ₁₂	PN10	PN16	PN25	PN40
80 to 300	3.2	4.0	5.0	1.6	2.5	3.2	4.0
350 to 600	2.5	3.2	4.0	1.6	2.5	3.2	4.0

700 to 1000	1.8	2.5	3.2	1.6	2.5	3.2	-
1100 to 2000	1.2	1.8	2.5	1.6	2.5	2.5	-

12.23. Asbestos Cement Pipe

Asbestos cement pipes are made of mixture of asbestos paste and cement compressed by steel rollers to form a laminated material of great strength and density. AC pipes are manufactured from class 5 to 25 and nominal diameters of 80mm to 600mm with the test pressure of 5 to 25 kg/Sq.m.

AC pipe can meet the general requirements of water supply undertakings for rising main as well as distribution main. It is classified as class 5,10,15,20 and 25, which have test pressures 5,10,15,20, and 25 kg/Sq.m respectively. Working pressures shall not be greater than 50% of test pressure for pumping mains and 67% for gravity mains as per IS 1592-1989.

Handling

Utmost care must be taken while loading, transportation, unloading, stacking and re-transporting to the site to avoid damage to the pipes.

Pipe Joints

There are two types of joints for AC pipes.

- Cast iron detachable joint, (CID) and
- AC coupling joint.

I.S. 6530-1972 shall be followed for laying A.C. pipes is shown in table 12.14.

TABLE 12.14

Test pressure for A.C. Pressure Pipes

Class of pipe	Test pressure Kg / Sq.m	Working Pressure Kg / Sq.m
Class 5	5	2.2
Class 10	10.0	5.0
Class 15	15.5	7.5
Class 20	20.0	10.0
Class 25	25.0	12.5

The nominal effective length (length between extremities of pipes with plain ends) and effective lengths of pipes with socket shall not be less than as shown in table 12.15 which provides pressure criteria for various classes of A.C. Pipes

TABLE 12.15**Diameter of pipe and Effective Length**

Nominal dia of pipe in mm	50	80	100	125	150	200	250	300
Length in m	3	3	3	4	4	4	4	4

12.24. G.I.Pipes

Ref: (IS: 1736/1986 & IS 1239 Part I)

Generally medium class GI Pipes are being used for OHSR and Pump set connections. The pipes are marked in yellow, blue and red for light, medium and heavy class pipes respectively. Further 20mm to 100mm dia GI Pipes are being used for various types of works. Normal weight of GI pipes against their internal diameter is shown in table 12.16.

TABLE 12.16**Verification of normal weights of GI Pipes**

Nominal bore in mm	Threaded ends (Kg/m)			Plain ends (Kg/m)		
	Light Class-A	Medium Class-B	Heavy Class-C	Light Class-A	Medium Class-B	Heavy Class-C
20	1.420	1.590	1.910	1.410	1.580	1.900
25	2.030	2.460	2.990	2.010	2.440	2.970
32	2.610	3.170	3.870	2.580	3.140	3.840
40	3.290	3.650	4.470	3.250	3.610	4.430
50	4.180	5.170	6.240	4.110	5.100	6.170
65	5.920	6.630	8.020	5.800	6.510	7.900
80	6.980	8.640	10.300	6.810	8.470	10.100
100	10.200	12.400	14.700	9.890	12.100	14.400

The Thickness of G.I.Pipes for different Dias of medium class-B pipe are shown in table 12.17.

TABLE 12.17

Nominal bore in mm	Pipe outer diameter		Thickness (mm)
	Maximum (mm)	Minimum (mm)	
20	27.3	36.5	2.60
25	34.2	33.3	3.20
32	42.9	42.0	3.20
40	48.8	47.9	3.20
50	60.8	59.70	3.60
65	76.6	75.30	3.60
80	89.5	88.00	4.00
100	115.0	113.10	4.50

12.25. Concrete Pipes

Reinforced concrete pipes used in water supplies are classified as P1, P2 and P3 with test pressures of 2.0, 4.0, and 6.0 Kg/Sq.m respectively (table 12.18). For use as gravity mains, the working pressure should not exceed 2/3 of test pressure. For use as pumping mains, the working pressure should not exceed 1/2 of the test pressure.

Jointing of pipes: The methods of jointing employed for concrete pipes are bondage spigot and socket joint (Rigid and semi flexible). Collar Joint, and flush joint (internal or external) in accordance with IS – 783. Amendment – 1, 1991 provides that all non pressure pipes should have flexible rubber ring joints.

- **Collar Joints (Rigid):** The collars of concrete pipes are 15 to 20 cm wide. Caulking space varies from 13 mm to 20 mm according to the dia of the pipe. Caulking material is slightly dampened mix of cement and sand 1:1.5 just to form a clod when pressed in hand which is rammed with caulking iron.
- **Spigot and Socket Joint (Rigid):** The spigot of each pipe is slipped home well into the socket of the pipe previously laid and adjusted in the correct position. The opening of the joint shall be filled with stiff mixture of cement mortar 1:2 which shall be rammed with caulking tool.
- **Spigot and Socket Joint (Semi Flexible):** The joint consists of specially shaped spigot and socket ends on concrete pipes. A rubber ring is placed on the spigot which is forced into the socket of the pipe previously laid. This compresses the rubber ring as it rolls into the annular space between the two surfaces of spigot and socket. Stiff mixture of cement mortar 1:2 is then filled by ramming into annular space and rammed with a caulking tool.

TABLE 12.18

Classification of concrete pipes for water supply use

Class	Description	Conditions where normally used
P1	R.C. Pressure pipes tested to hydrostatic pressure @ 0.2 MPa	For use on gravity mains, site test pressure not exceeding 2/3 rd of hydrostatic test pressure
P2	R.C. Pressure pipes tested to hydrostatic pressure @ 0.4 MPa	For use on pumping mains working pressure not exceeding ½ of the test pressure
P3	R.C. Pressure pipes tested to hydrostatic pressure @ 0.6 MPa	For use on pumping mains working pressure not exceeding ½ of the test pressure

The dimensions of reinforced concrete pipes for different test pressures as per IS-458 are shown in table 12.19.

TABLE 12.19

Class P1 –Reinforced concrete pressure pipes-Test Pressure at 0.2 MPa (IS-458)

Dia of pipe in mm	Barrel dimensions		Weight per M in Kgs	Weight of collar in Kgs
	Length in mts	Min. thickness in mm		
300	2.0, 2.5, 2.3	30	75	14.50
350	2.0, 2.5, 2.3	32	92	17.70
400	2.5, 3.0	32	104	23.50
450	2.5, 3.0	35	128	30.85

500	2.5, 3.0	35	141	34.90
600	2.5, 3.0	40	193	42.60
700	2.5, 3.0	40	223	51.25
800	2.5, 3.0	45	287	60.80

Class P2 –Reinforced concrete pressure pipes-Test Pressure at 0.4 MPa (IS-458)

Dia of pipe in mm	Barrel dimensions		Weight per M in Kgs	Weight of collar in Kgs
	Length in mts	Min. thickness in mm		
300	2.0, 2.5, 3.0	40	103	25.4
350	2.0, 2.5, 3.0	45	134	38.0
400	2.5, 3.0	50	170	40.0
450	2.5, 3.0	50	188	45.3
500	2.5, 3.0	55	230	66.2
600	2.5, 3.0	65	326	78.4

Class P3 –Reinforced concrete pressure pipes-Test Pressure at 0.6 MPa (IS-458)

Dia of pipe in mm	Barrel dimensions		Weight per M in Kgs	Weight of collar in Kgs
	Length in mts	Min. thickness in mm		
300	2.0, 2.5, 3.0	45	117	45.3
350	2.0, 2.5, 3.0	55	-	-
400	2.0, 2.5, 3.0	60	-	-

12.26. Pre-stressed Concrete Pipes

The PSC pipes are suited for water supply mains where pressure is in the range of a 6Kg/Sq.m to 20 Kg/Sq.m are encountered.

Specials: The specials for these pipes such as bevel pipes, bends, flanged tees, tapers and adopters to flange the couplings are usually fabricated as mild steel fittings lined and coated with concrete.

Joints: The standard joint consists of steel joint rings and a continuous solid rubber ring gasket. The field joint can be over lapping/sliding, butt welded or with confined rubber ring as per the clients requirement. In the case of welded & rubber joint recess is normally grouted and the internal joint space may or may not be pointed with mortar.

Jointing: I.S 784 applies for laying and jointing pre-stressed Concrete pipes. These pipes have flexible joints to be performed by rubber gaskets. The pipes are provided with spigot and socket ends to receive rubber gaskets. The joint with rubber gasket remains water tight under normal service conditions. For specifications of rubber gasket IS – 5382 is to be referred.

Permissible Pressures for PSC Pipes

Working Pressure: Pressure based on hydraulic gradient.

Field Test Pressure: 1.5 times the working pressure or 1.1 times the static pressures which ever is more.

Factory Test Pressure:

- Field test pressure + 1.0 kg/Sq.m , for pipes below 10 kg / Sq.m and
- Field-test pressure + 2.0 kg / Sq.m, for pipes above 10 kg / Sq.m.

12.27. Unplasticised PVC pipes

Applicable Codes

Latest version of following codes shown in table 12.20 shall be applicable to the work of laying, jointing, testing and commissioning of UPVC pipeline for water supply application.

TABLE 12.20

IS Code No.	Title
IS 4985-1988	Specifications for Unplasticised PVC pipes for Potable Water Supply
IS 7834-1987 (Part I) Part B)	Specifications for injection molded PVC socket fittings with solvent cement joints for water supply.
IS 12235 – 1986	Methods for test for Unplasticised PVC pipes for Potable Water Supply
IS 7634-1975	Code of Practice for plastics pipe works for potable water supplies.
IS 2692-1978	Ferrules
IS 3950-1979	Surface Boxes for Sluice Valve Chambers
IS 778-1984	Copper Alloy Globe Gate and Check Valve for Water Supply purposes
IS 2065-1983	Code of practice for water supply in building

The internal and external surface of the pipe shall be smooth and clean, free from grooving and other defects. The ends shall be cleanly cut and shall be square with the axis of the pipe or chamfered at one or both the ends. Slight shallow longitudinal grooves or irregularities in the wall thickness shall be permissible provided the wall thickness remains within the permissible limits. The wall of the socket portion and the all of the plain pipe shall not transmit more than 0. % of the visible light falling on them when tested in accordance with IS 12235 Part 3 -1986.

Tolerance in diameters of the pipes and in wall thickness shall not exceed the limits given in the IS Code 4985-1988.

The pipes shall be supplied in straight lengths of 4, 5 and 6 meters with a tolerance of +100mm and – 0mm

Test Pressure & Working Pressure

The pipe shall with stand a hydraulic pressure equal to 36.0 MPa (360 kgf/Sq.m) for one hour at 27⁰. The range of diameter for various working pressure are as given in table 12, 21.

TABLE 12.21

Sr.No.	Working pressure MPa (kgf/Sq.m)	Range of diameter in mm
1.	0.25 (2.5)	90-630
2.	0.4 (4.0)	63-630
3.	0.6 (6.0)	40-630
4.	1.0 (10)	16-630

Pipes shall be suitable for safe working stress of 8.6 MPa (86 Kgf/Sq.m)

For further details of PVC and HDPE pipes refer to:

IS 7834 – 1975 Parts 1-8
IS 8008 – 1976 Parts 1-7
IS 7634 – 1975 Parts 1-3
IS 3076 – 1985
IS 4984 – 1987

12.28. Glass Fibred Reinforced Plastic Pipes

Glass fibred Reinforced Plastic (GRP) pipes are now being manufactured in India conforming to IS 12709. The diameter range is from 350mm to 2400 mm. The pressure class is 3,6,9,12 & 15 kgs/sq.cm. The field test pressures are 4,5,9,13.5,18,22.5 kg/sq cm. The factory test pressures are 6,12,18,24 & 30 kgs/sq cm. Depending on the type of installation, overburden above the crown of the pipe and the soil conditions, four types of stiffness class pipes are available. Standard lengths are 6 & 12 meters, however custom made lengths can also be made.

12.29. Service Connections

For providing household or stand post connection ferrule should be used. The ferrules shall generally conform to IS: 2962. It shall be of non-ferrous materials with a CI bell mouth cover and shall be of nominal bore as specified. The ferrule shall be fitted with a screw and plug or valve capable of completely shutting of the water supply to the communication pipe, if and when required.

12.30. Water Meter

Water meters wherever used shall be of approved make and design shall be supplied for installation at location as shown in drawings. The water meters shall meet with the requirement of local water supply authorities. Suitable isolation valves and chambers or wall meter box to house the meters shall also be provided along with the meters.

The meters shall conform to Indian Standard IS: 779 and IS: 2373.

12.31. Filter Sand for Slow Sand filters

The filter media shall be graded natural sand with an effective size of 0.25 mm to 0.35 mm, and uniformity coefficient of 3 to 5. The micaceous matter in the sand shall be less than 1% and the loss of weight on immersion in hydrochloric acid shall not be more than 5%. Silica Content of the sand shall not be less than 95%. Depth of sand bed in each filter shall not be less than 0.4 to 0.5m. as a layer of sand 10 to 20 mm will be removed every time during cleaning. A new filter should be provided with a initial sand depth of about 1.0 m. Re-sanding will then become necessary on it once in two or three years. The sand media shall be supported on 0.2 to 0.3 m thick bed of gravel (HB Metal). Size of individual gravel shall be above 8mm. Filter media and supporting gravel shall be conforming to IS:8419 (Part 1) 1977.

12.32. Gate Valves:

Gate Valves shall be either solid wedge or knife gates unless specifically defined on the drawings. All valves shall be double-flanged. Valves from Indian manufacturers are in the size range 50mm to 300mm shall conform to IS: 780 and those of size range 350mm and larger to IS:2906. Imported valves shall conform to the relevant British or American Standards Valve shall be of suitable pressure rating which shall not be less than twice the normal operating pressure.

Design

The design of the valves shall be such that erosion, cavitations, vibration and head loss (in the fully open position) shall be with a minimum external lubrication. The valves should be capable of being opened and closed against working pressure which exceeds the maximum working pressures by 15 percent.

Materials: The materials used for the manufacture of each component shall be the best available for the specific purpose and shall not, in any case be inferior to the following:

Cast Iron	IS 210 Grades
Stainless Steel	IS 1570 Grade, BS 970 Types EN, ASTM A 473
Gun Metal	BS 1499-LG – 2 C or the equivalent Indian standard
Cast Steel	Plain Carbon Steel complying with IS 1570 Grade, or BS 970 Grade 431 S 29

12.33. Format for Test Report on Bricks

Source Sample	:	-
Number of Samples tested	:	-
Name of the Sub work	:	-
Name of the work	:	-
Sub Division	:	-
Division	:	-
District	:	-
Period test	:	-
Technical reference	:	IS 3495 - 1992 & IS 1077-1992

1. Compressive strength

S.No	Details of sample	Size in mm	Comp Strength (N/Sqmm)	Average Comp Strength (N/Sqmm)	Requirements as per IS 1077
1					
2					
3					
4					

2. Water absorption

SNo	Details of sample	Size in mm	Water absorption %	Average Water absorption %	Requirements as per IS 1077
1					The average water absorption shall not be more than 20%
2					
3					

12.34. Format for Test Report on Fine aggregate

Source Sample	:	-
Number of Samples tested	:	-
Name of the Sub work	:	-
Name of the work	:	-
Sub Division	:	-

Division :-
District :-
Period test :-
Technical reference :- IS 2386(Part I to VII) 1963/1990

IS sieve Designation	Cumulative Percent		Specification as per For Fine Aggregate (Percentage Passing)		
	Retained	Passing	Zone-I	Zone-I	Zone-I

Tested conducted	Results	Requirements
Silt content	--	--

12.35. Format for Test Report on Coarse aggregate

Source Sample :-
Number of Samples tested :-
Name of the Sub work :-
Name of the work :-
Sub Division :-
Division :-
District :-
Period test :-
Technical reference :- IS 2386(Part I to VII) 1963/1990

Sieve Analysis for 40 mm aggregate

IS sieve Designation	Cumulative Percent		Specification as per For Fine Aggregate (Percentage Passing)	
80.0mm				
63.0mm				
40.0mm				
20.0mm				
12.5mm				
10.0mm				
4.75mm				

Sieve Analysis for 20 mm aggregate

IS sieve Designation	Cumulative Percent		Specification as per For Fine Aggregate (Percentage Passing)	
40.0mm				
20.0mm				
12.5mm				
10.0mm				
4.75mm				

Sieve Analysis for 12.5 mm aggregate

IS sieve Designation	Cumulative Percent		Specification as per For Fine Aggregate (Percentage Passing)	
20.0mm				
12.5mm				
10.0mm				
4.75mm				

Format for Test Report on Physical Properties of cement

Source Sample :-
 Number of Samples tested :-
 Name of the Sub work :-
 Name of the work :-
 Sub Division :-
 Division :-
 District :-
 Period test :-
 Technical reference :- IS 8112-1989

Sl.No.	Test conducted	Results	Requirements as per	Remarks
1.	Normal consistency		Not specified	
2.	Initial setting time		Shall not be less than 30 minutes	
3.	Final setting time		Shall not be less than 600 minutes	
4.	Compressive strength a) 72 ± 1 h (average of three results)		Shall not be less than 23.0 Mpa	
	b) 168 ± 2 h (average of three results)		Shall not be less than 33.0 Mpa	
	c) 672 ± 4 h (average of three results)		Shall not be less than 43.0 Mpa	
5.	FINENESS (by Blaine's air permeability method)		Shall not be less than 225 m ³ /kg	
6.	SOUNDNESS (by Le-Chatelier's method)		Shall not be more than 10mm	

Format for Test Report on Steel

Source Sample :-
 Number of Samples tested :-
 Name of the Sub work :-
 Name of the work :-
 Sub Division :-
 Division :-
 District :-
 Period test :-
 Technical reference :- Fe 250 / Fe415

a) Proof Stress

Dia of bar	Wt. Kg/m	Proof of stress N/mm ²	Ultimate tensile stress (N/mm ²)	Elongatin (%)	Bend	Rebend

b) Permissible limits for weight:

Nominal size	Range of weight for batch (Kg/m)
8.0	
10.0	
12.0	
16.0	
20.0	
25.0	
32.0	

CHAPTER – 13

13.CONSTRUCTION MANAGEMENT

This chapter explains the actions to be taken during the progress of work. The water source is established during planning stage. Based on the yield, the project planning, design, estimate and tender action will be done.

13.1. Bore wells

The source is to be selected during planning stage. If existing bore well, it should be flushed once again and the yield ascertained for its dependability as regards to quality and quantity before commencement of civil works. Procurement of pump and rising main should take place only after above actions are completed.

Bore well Drilling

- Drilling should be done upto the loose formation by Down The Hole Rig (DTH) to avoid the collapsing of bore well upto the hard strata met with. To arrest the collapsing of bore PVC casing pipes of required thickness may be driven inside the bore well. Further drilling has to be done to the depth recommended by Hydro geologist.
- During drilling spring details like depth, spring yield and classification of hard strata samples have to be collected.
- The drill bit should not be less than 150mm dia.
- The depth at which the water level is touched should be noted.
- Verticality of bore from top to bottom should be strictly maintained.
- The inner clear finished diameter of bore well should not be less than 150mm through out the depth.
- The yield in the bore well should be verified with 90° V notch to assess the yield at various depths.
- After drilling the bore well to the recommended depth, the bore well has to be flushed for minimum 30 minutes thoroughly for expelling the fine and silt particles until clear water is obtained.
- During flushing of bore wells yield should be assessed by 90° V notch. Water samples should be collected and sent to the laboratory for testing. After completing the works, the drilling may be stopped and drilling rods may be removed from the bore well site. Necessary bore cap has to be provided to protect the bore well.

Inspect as many wells in the vicinity of interest as possible. If the inspected wells encounter groundwater at approximately the same elevation and ground water does not occur in discontinuous lenses, groundwater should be present in the subsurface at roughly the same elevation as in the inspected wells.

Careful observation to the drilling reveals one or more of the following signs indicating that a good water-bearing layer has been reached.

- The cuttings may indicate that the drill bit has hit a zone of sand and/or gravel (formations which usually produce abundant volumes of water if they are saturated). This

-
-
- is the most widely useful indicator and requires continuous, careful sampling of drill cuttings;
- There is often a significant increase in the speed with which the hole is being drilled when a permeable sand aquifer is reached;
 - When drilling into a gravel aquifer the gravel will often cause the bit to bounce;
 - Sometimes the drilling fluid (drilling mud) suddenly starts to thin appreciably;
 - There may be a noticeable drop in the level of drilling fluid. If a formation is permeable enough to take water, it may also yield enough water for a well.
 - The water temperature may drop when groundwater is encountered.
 - In general, boreholes should be completed as far as possible into aquifers because;
 - More of the aquifer can supply the intake portion of the well, resulting in a higher yielding well (increased specific capacity); sufficient saturated thickness is available to maintain well yield even during periods of severe drought or heavy pumping;
 - Where clay soils are found, it is often important to drill down and slightly into underlying rock to find significant quantities of water.
 - After stopping drilling, ensure that the borehole is kept full of drilling fluid until the casing and screen have been inserted into the well, gravel packed and the sanitary grout seal placed.

13.2. Open Wells

Open wells are shallow wells, which are usually confined to soft ground, sand and gravel. These wells having bigger diameters and are suitable for low discharges of the order 18 cum per hour. The diameter of the open wells varies from 3 to 10 meter, and the depth varies from 10 to 15 meter. The walls of open well may be built with Pre-cast RCC rings, RCC walls, and Stone masonry. The yield of an open well is limited and the groundwater storage is also limited. To improve the yield of open well an in-well bore well of 100 mm to 150 mm is drilled at the center of the open well, so as to tap the additional water from an aquifer or from a fissure in a rock. The Pump set will be fitted for drawl of water from well.

Construction of RCC steining Well

- Open well excavation may be done upto sub soil water table level with required slope.
- The RCC curb in 1:1½:3 should be cast to required size with a cutting edge at the bottom. The curb should be projected 5 cm beyond the outside face of the well steining to facilitate easy sinking.
- The side wall inner and outer vertical rods should be tied up with curb rods at specified spacing. The hoop rods for inner and outer vertical rods may also be tied up properly.
- Cement concrete 1:1½:3 (M-20 mix) to be used should be mixed in the mixer machine and vibrators should be used for proper mixing and compaction.
- The alluvial soil or sand from inside the well is dredged and removed either mechanically or by manually using divers with diving equipment for every lift of concrete laid.
- In order to reduce the velocity of entry of flow at the bottom of RCC Well and to abstract more yield, weep holes are usually provided in the well steining at suitable intervals horizontally and vertically with 32mm or 40 mm OD PVC 4 Kg/SqCm pipes fixed into

the well steining with wire gauge at outer end of pipe to prevent entry of fine sand or red soil particles, into the well. During sinking of well the wire gauge fixed may be subjected to damage and thereby the purpose could not be achieved. On the other hand and to overcome this problem, the PVC perforated cap of small slots with wire mesh may be provided to the PVC pipe. The PVC pipe extended 5 cm from side wall inner surface and slanting towards well should be tied up with side wall reinforcement rigidly for averting disturbance.

- Sinking may be done upto the required depth by dredging of soil.
- After completing of sinking work, the bottom of well should be cleaned by bailing out of water from the well completely.
- After recuperation, the quality and quantity of water in the open well should be assessed.
- Necessary disinfection should be done with chlorine solution for the water recouped in the open well.

13.3. Pump Rooms and Pump Sets Installation

The Pump Room is constructed to house the Panel Board, and for erecting the centrifugal pump set or jet pump set. When the road level and Ground Level of proposed pump room are of same level, Pump room with brick work may be provided without columns.

- Pump room should be constructed near to the source, to minimize the cable size and Length.
- Construction of a new pump room may be avoided, if the community prefers to use the existing Panchayat owned building, if situated nearby the source to minimize the estimate cost.
- Necessary lighting arrangements inside and outside the pump room should be provided for the convenience of the Pump Operator to operate the Pump set during night hours
- Proper earthing should be ensured as per rule,
- Pump room door should be fixed in such a way that it can be opened outwards only.
- The pump rooms shall be constructed for centrifugal/jet pump sets

Installation of Submersible Pumps

The Submersible pump unit comprises of single or multistage centrifuge pump and water filled squirrel cage motors. Both pump and motor have water lubricating plane bearings. Submersible pumps shall be installed in a bore well such that the motor assembly is always submerged in water. Hence, normally they are installed at 1.5-2.0 m below the lowest safe yield level during summer under continuous operation.

Hence it is necessary to install electronic water level indicators to read the water level in the bore well ensuring the required minimum submergence (1.5m) also to avoid drawing of the silt/sand from bottom it is preferable that lowest part of the pump is 3.0 m above bottom of the well. The motor assembly is suspended through the riser pipe, which in turn is clamped at the top of the casing pipe. The insulated cable is tied to the riser pipe at regular intervals. The casing pipe is taken to height of about 0.45 m above the ground level and is covered in order to prevent misuse.

This can be installed vertically or horizontally in clean water. The motor is to be filled with water before installation. This pump will give trouble free satisfactory service if it is properly installed and maintained. Maximum installation depth is 160 meters. Pumps should never be allowed to run dry.

Submersible pump shall be always supplied with the following

- Electric Motor with short length of cable
- A special device with relay warning system, bell or light for protection against dry running.

Pump to be installed as per the instruction manual of the pump manufacturer by a trained technician. Pump can be installed vertically or horizontally but water level should be at least 1.0 m above the pump level. Pump shall be so installed that sand and mud do not settle on the motor. Care shall be taken in connecting the motor terminal to electrical supply so that pump rotates in the correct direction.

In case direction of rotation is not marked, same can be determined as below.

For finding out proper direction of rotation, pump is run with closed discharge valve for 5 minutes in clockwise and 5 minutes in anti clockwise direction with valve on the discharge line closed. While operating in either direction pressure is read from the pressure gauge. Different pressure reading will be observed in both the cases. Direction of rotation giving higher reading will be the correct direction of rotation for the pump.

Precautions for proper installation of submersible pumps

- Motor is filled with adequate quantity of cold fresh drinking water before it is coupled to the pump
- No air is entrapped while filling the water in the motor.
- Fill water very slowly
- Do not use any gasket in between while coupling with motor.
- Do not temper with the important assembly settings carried out at workshop like axle play of motor and pump since these have been done under expert supervision with proper tools. In case pump set is required to be disassembled at site, it should be carried out by factory-trained mechanic of the manufacturer.
- Do not pull the pump with the electric cable.

Commissioning and Start-up

During the initial start up pump should be run for 10 minutes with discharge valve slightly open because powerful suction might cause the large amount of sand to be entangled with the water and damage the pump, once the pump is put to operation. Do not keep the pump idle for more than 2 weeks. It is ideal to run pump at least five minutes in a week. Always ensure that the pump is not running dry

Installation of Centrifugal Pumps

Centrifugal pumps shall be installed for open well or intake well such that the motor assembly is fitted in pump room and the delivery point is fitted in water at collection level. The bottom of pipe is fitted with foot valve and strainer.

Horizontal centrifugal Pump is most commonly available pump as it is extensively used in water supply schemes. Centrifugal pumps are supplied with electric motor fitted on the common base frame.

Pump shall be installed as per the instructions of manufacturer. Proper installation of pump is of utmost importance for satisfactory and trouble free working of the pump. Normally pumps are supplied with a matching electrical motor. Pump and motor are mounted on a common base frame and coupled by a coupling. This assembly is required to be properly

secured on a cement concrete foundation and then connected with suction and delivery pipeline.

Foundation

Foundation must be sufficiently strong to absorb the vibration. Pump base plate shall be properly leveled and evenly supported to avoid destruction. Grouting shall be carried out after the alignment is completed. Foundation bolts to be tightened evenly and after giving setting time of 48 hours.

Suction and Delivery Lines

After foundation is completed place the equipment in the order. Suction and delivery pipe size should be of bigger size than suction and delivery ports of the pump. Both piping must have independent support to avoid the undue strain on the pump nozzle. Suction and delivery pipe strain may result in wearing of the ball bearing and bending of the pump shaft. Suction line should be correctly laid out. Foot valve is provided in proper working condition and dust free. The suction piping should be leak proof to facilitate the trouble free priming. On delivery line a non-return valve and gate valve should be installed to protect the pump from excessive back-pressure. Pressure gauge with the valve to be provided before the delivery valve.

Electric Motor and Electric connection

Electric motor if supplied with pump should be decoupled from the pump and no load trial be carried out before connecting to pump. Direction of motor shall match the direction of rotation of pumps. (Normally marked on the pump casing) re coupling of motor of no load trial shall be done with proper alignment. Motor shall be provided suitable earthing.

Coupling

This is to transmit the energy from electric motor to pump. Following different types of coupling are normally provided in the pumps used for water application.

- Pin Bush type coupling
- Unit type coupling
- Love joy coupling

Coupling has two halves. One half of the coupling is fitted on the pump shaft with a bore keyway and grub bolt, other half of coupling is fitted on the motor shaft with bore keyway and grub bolt. Both halves are connected for torque transmission, with the pin and bush. After proper alignment of coupling pin bolt should be tighten Gap between two halves of coupling should be maintained 4 mm. Alignment should be checked parallel and angular. After installation information about each pump shall be recorded for future use format for recording information about pump is given in Annexure.

13.4. Accessories

Indoor control panels where pump chamber are provided or out door type control panel for bore well pump sets will have provision for energy meter, main switch, starter, single phase preventer, capacitor, etc

- a) Switches: A main switch of adequate capacity to disconnect power supply shall be provided after the meter. This will enable to disconnect the service immediately in case of any emergency or for maintenance purpose.
- b) Starter: Starter with over load relay is provided to start and stop the motor and to protect it against any over load. Over load may be either electrical or mechanical
- c) Capacitor: Installation of capacitor of suitable rating in the motor circuit will improve the power factor and reduce energy consumption. The running cost of the motor will also be reduced. The recommended capacitor ratings are shown in table 13.1. It is essential to provide capacitor to avoid penal action from the AP Transco. .
- d) Single phase preventer:- In three phase circuit, three fuses are provided (1 for each phase). If in any one phase were to blow or any one phase is disconnected from service during running of the motor, the motor keeps running drawing excess current from the two lines and hence causing damage to the motor. If a single phase preventer is provided in the circuit, it will sense the operating coil and trips the starter and protects the motor from burning.
- e) Voltmeter and Three Phase Ammeters: These meters will indicate whether system voltage is within permissible range for the motor or to know whether motor is drawing current equally on all three phases. The functioning of Voltmeter is very important, voltage being low in villages damaging the motors.
- f) Selector Switch: Selector switches of adequate capacity shall be used wherever more than one pump is installed. The selector switches will enable to operate any one of the pump or both the pumps from a single switchboard.

Pump or both the pumps from a single switchboard

TABLE 13.1

Sl No	Range of Motors	Starter Type	Cables (Copper conductor wires)	Capacity or KVAR	MCB Amps	Volt meter	Ammeter
1	Upto & inclusive of 3HP	Direct online	2.5 Sq.mm	1	20	0 to 500 V	0-15 A
2	Above 3 HP upto and inclusive of 5 HP	Direct online	2.5 Sq.mm	2	20	0 to 500 V	0-15 A
3	Above 5 HP upto and inclusive of 7.5 HP	Start delta	4.0 Sq.mm	3	32	0 to 500 V	0-30 A
4	Above 7.5 HP upto and inclusive of 10 HP	Star delta	4.0 Sq.mm	4	40	0 to 500 V	0-30 A
5	Above 10 HP upto and inclusive of 12.5 HP	Star delta	6.0 Sq.mm	5	40	0 to 500 V	0-60 A
6	Above 12.5 HP upto and inclusive of 15 HP	Star delta	6.0 Sq.mm	5	63	0 to 500 V	0-60 A

Electrical Connections

Use of underground cable is usually made for service connection from AP Transco supply point to energy meter fixed inside the control board. Internal connections from meter to switch to starter to capacitor and to single phase preventer etc are done using suitable P.V.C. insulated copper wires of 440 volts grade. From load side terminals of starter to submersible pump, suitable water proof PVC insulated copper cable of 3 core type has to be laid. Use of under ground cable of 4x105 mm dia aluminum conductor, PVC insulated, PVC sheathed 1.1 KV class is usually used from AP TRANSCO supply point to energy meter up to 15 HP loads, Use of 3 core PVC insulated PVC sheathed copper conductor, water proof cable is used from starter terminals to pump terminals (inside bore).

Safety Procedures

- After installation, it shall be tested to ensure that the wires/ cables used are sufficiently insulated to avoid leakage of current.
- For safety, all the metallic casing of enclosure of switches etc must be solidly connected to earth. The body of the out door kiosks shall have a separate and efficient earth connection.

13.5. Civil Works

The working levels shall be taken from the source point to service reservoir and ascertained that the levels taken with that projected in the drawings proposed during planning and preparation of DPR. If any variation is noticed the necessary action shall be taken to redesign the pumping main and pump machinery in accordance with the working levels now obtained, as possibility of changes in location of OHSR are quite evident in villages for reasons necessitating acquisition of land required for construction or change of sources.

Civil works construction will start once contract procurement process is over and work orders are issued. Transmission line and reservoir works can be taken simultaneously and immediately. As per experience, Distribution works are likely to deviate from the original plans due to change in user demand. Therefore, distribution work can be taken up after finishing pumping main and storage tanks. Accordingly procurement of distribution pipes can be phased out suitably.

Ground water recharging works should be taken after rainy season and be completed before the next rainy season or at least constructed to a safe level so that it with stands the impact of the floods. Sanitation work can commence simultaneously but water supply should be available by the time sanitation works are completed and put to use.

Splicing of reinforcement bars and cranking shall be in accordance with typical details or as detailed or indicated. Laps shall conform to IS Specifications. Welding of reinforcement shall be in accordance with IS Specifications. Welding shall be done during day time only. These specifications are intended to generally describe the quality of materials and workmanship to be used for the finished work. They are not intended to cover minute details; it is assumed that only the best quality of materials and workmanship shall be used on the proposed work and that the work shall be executed in accordance with the best latest engineering practices as per the instructions and directions of the engineering who is supervising the work.

The works envisaged in the proposed project shall, unless otherwise stipulated, be carried out as per the various Indian Standard Specifications/code of practice as may be applicable. Reference to various IS Code of practice shall mean the latest editions.

13.6. Construction of Over Head Service Reservoirs (OHSR)

Selection of Site

The following precautions should be taken before selecting the site for construction of OHSRs.

- The site should not be selected in made up soil or loose earth.
- Trial pits have to be dug upto the depth of 1.00m below the foundation level to assess the nature of soil met with for knowing the approximate bearing capacity of soil for laying foundation.
- If soil met with is loose or block cotton or soft clay and if no other site is available, the SBC of soil may be obtained from the soil mechanics laboratory. If SBC is found to be less, raft foundation may be provided for the columns.
- For safety point of view, the site selected for OHSR construction must be free from Over Head Power Lines, trees etc.,
- The site selected should be at an elevated place and preferably at middle of village to affect equitable supply to all parts of the village.
- The OHSR site selected should not be nearer to the Waste Water Pond, burial ground and garbage dumping yard.
- The OHSR should not be constructed in the private land and if there is no other alternative, the consent letter from the land owner should be obtained legally.
- Separate OHSR may be proposed to serve certain pockets having no supply, based on the existing population.
- If any existing OHSR is not utilized, the same may be put into beneficial use after attending the repairs.

Procedures to be followed during Construction of OHSR

Checking of reinforcement and cover

- The diameter, type and spacing of reinforcement may be verified with reference to drawings and agreement specifications thoroughly.
- Proper cover of 5cm, 4 cm, 2.5cm may be provided for footings, columns, beams and slabs respectively with cement concrete cover blocks
- Stone chips or similar pieces of bricks etc, should not be used for maintaining cover.
- Concrete spacer blocks or concrete rings of required cover preferably tied with rods, by binding wire should be used to prevent their displacement.
- Rusted steel reinforcement or reinforcement coated with mud, oil, and grease should not be used.
- Cut length rods should not be used for main reinforcement to minimize the laps.
- The reinforcement should be bound properly with binding wire.
- Stirrup hooks should be cranked inside for proper binding.
- Extra cover for R.C.C. works in areas located within 15 km distance from sea shore may be provided to avert corrosion effect.

Centering and Strutting

- Proper check should be made for the verticality of the form work of columns and side walls with plum-bob during execution.
- Apply non staining oil or grease to column moulds, shuttering of beams, side walls and slabs etc, to prevent absorption of water from concrete.
- Provide tight joints between shuttering sheets to prevent leakage of cement slurry.
- Steel moulds and shuttering should be used for columns, braces, side walls, Floor slabs and roof slabs.
- Mango planks should not be used.
- Shuttering made out of bamboo with mud plaster on top should not be entertained.
- Centering may be removed after two days for sides of slab, beam and columns to aid curing.
- The floor slab strutting should be independent without touching the other components of the structure. It should not be supported over the braces.
- The struts should be firmly fixed to keep the level of form work and should be checked to see whether supported on the firm ground with wedging.
- The level of form work for braces, floor slab and roof slab provided should be checked with tube level.
- Single strut should be provided to support the floor slab form work at suitable intervals. They should be sufficiently strong and sturdy.

Mixing of concrete

- Only after testing and satisfying to the required quality standards, sand, cement HBG Metal, Steel and Water may be permitted to use in the work.
- Mixer machine should be used for mixing concrete.
- Bulkage of sand should be checked and the same quantity should be allowed.
- Slump cone test should be done for assessing the water cement ratio.
- Mixing concrete on bare ground instead of on platform should not be allowed.
- Add water in the mixer hopper with a container of specific capacity of 23 liters per 1 bag of Cement for 1: 1 ½: 3 Mix.
- M 20 (1: 1 ½ :3) concrete may be used for all components of works
- Minimum 3 Nos. of concrete cubes of 15cm x 15cm x 15 cm must be casted at different intervals during concrete for each component of OHSR and tested on 7th day and another on 28th day in the nearby laboratory to test the quality of concrete.
- Vibrator should be used for better compaction.
- Necessary anti corrosive measures are to be taken to protect the steel rods in coastal areas.

Curing of concrete

- Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacking canvas or similar materials and kept constantly wet for atleast 21 days from the date of placing the concrete.

Precautions to be taken

- Column footing gaps should be filled up with ordinary soil watered and consolidated properly, atleast 10 days after laying of footing concrete.
- The honey comb to be touched neatly with cement mortar of 1:2 then and there.

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- Centering sheets should be smooth enough to get smooth finishing. Finishing should be such that no more finishing is warranted.
 - Before laying concrete for floor slab and roof slab the props should be checked properly to avoid sliding of concrete.
 - Polyethylene cover sheets may be spread over the centering sheets of floor slab and roof slab to prevent leakage of cement slurry and for attaining smooth finish.
 - Floor beam and brace side main rods at top and bottom should be cranked suitably, inserted and tied up with inner side of column rods.
 - The top level of PCC, Ground level. Brace, Middle brace, Floor slab, roof slab should be checked with tube level for attaining uniform level.
 - Floor slab, side wall, roof slab diameter should be checked perpendicularly and diagonally, in four direction to obtain uniform diameter.

Miscellaneous Works of OHSR:

- Inside ladder, manhole frame and cover should be provided as per Agreement specifications and drawings and to be fixed properly.
- GM Gate valves bearing ISI Mark, CM/L No. Batch No. Trade Mark should be fixed for outlet, scour etc.
- Overflow pipe should be fixed upto MWL of OHSR with GI medium class pipes only
- Inlet pipe laid on top of roof slab should be supported on Pillars suitably
- Separate Pipe for scour may be fixed and laid upto the nearest drain, linked with over flow pipe.
- The outside MS Ladder should be fixed rigidly at bottom with 0.30m raised CC (1:3:6) platforms, since corrosion occurs if fixed at ground level.
- The MS angles of MS ladder may be extended horizontally for 0.6m on roof slab and fixed with concrete rigidly at top. For ascending to roof slab of OHSR easily, suitable handrail of 16mm dia MS rods welded with both angles of MS ladder should be extended for 0.60m above roof level, cranked to 0.60 m horizontally, then bent downward and welded with MS angle suitably.
- Support angle of 50 x50 x 6mm should be strutted with MS ladder at middle to avoid buckling.
- MS door with locking arrangements have to be provided at 2.00m height of MS ladder for safety.
- MS ladder, metallic pipes and specials connected to pump sets and water retaining structures may be painted with anti corrosive paint to avoid corrosion.
- The staging height of OHSR may be ascertained to effect supply at $0.60\text{m}^3/\text{Sec}$ and to ensure 6 m residual head at all tapping points, if not feasible, locate at other high level point other than the location selected.
- Separate out lets may be provided in the floor slab of OHSR for zonalising the distribution Systems
- The gate valves should be fixed at a convenient height from ground level for each operation within the reach of children.
- Flange set with nipples may be used for fixing valves so as to disconnect and to fix easily.

Note: The OHSR may be constructed as per the model drawings and detailed estimates being adopted at present.

IS: 3370 (Part 1 to 2) -1965, IS: 3370 (Part 3 to 4) -1967. The staging of tank will be as guided by IS: 11682-1985.

- **Excavation:** The excavation shall be of the width and length necessary for the construction of foundations or other works below ground. The depth of all excavation shall be decided by the Engineer-in-charge depending upon the bearing capacity and other requirements. Excavation shall be left open for as short as period as practicable. The sides of excavation shall be trimmed, if necessary. The bottom shall be cleaned and if in loose or disturbed ground shall be well rammed.
- **Preparation of Ground below Permanent Construction:** Plain concrete in foundation shall be placed in direct contact with bottom of excavation. The bottom of excavation is covered with a 'blinding' layer or screed of (1:3:6) or M-10 concrete not less than 50mm thick with smooth surface. The required cover of concrete under the reinforcement shall be entirely above the blinding layer. A sliding layer of bitumen paper or other suitable material to destroy the bond between screed and floor concrete shall be provided (IS: 3370).
- **Bending of Reinforcement:** Bars shall be bent cold unless it is approved that large bars may be bent hot. No reinforcement shall be bent when in position in the works. Bends shall comply with dimensions given in Bending Schedule. The internal-radius of bend shall not be less than twice the size of the bar for plain round mild steel bars or 2.5 times the size for high yield bars.
- **Fixing Reinforcement:** Reinforcement shall be accurately fixed and maintained in a position as described in the drawing. Bars at passing points shall be securely wired together at all such points with No. 16 gauge soft iron annealed tying wire. Binders and the like shall tightly embrace the bars with which they are intended to be intact and shall be securely wired. Immediately before the concreting, the reinforcement shall be examined for accuracy of placing and cleanliness and corrected if necessary. Reinforcement projecting from work being concreted or already concreted shall not bend out of its correct position for any reason.
- **Clear Cover:** This is a single most important feature influencing the behavior and durability of the structure in aqueous environment. Usual range of cover is 1 to 1.5 the dia of bar atleast 15mm, on longitudinal bars of beam atleast 25mm, and on longitudinal bars of column atleast 40mm. The cover of concrete to the reinforcement shall be as directed in drawings within a tolerance of 5mm under and over by means of distance pieces of cement mortar or other approved material.

The vertical distance required between the successive layers of bars in beams etc shall be maintained by steel spacer bars inserted at such intervals that the main bars do not sag between adjacent spacer bars.

- **Form Work:** Form work for concrete shall be rigidly constructed of approved materials and shall be true to the shape and dimensions described on working drawings. Faces in contact with concrete shall be free from adhering grout, projecting nails, splits or other defects. Joints shall be sufficiently tight to prevent the leakage of cement grout.

Approved mould oil or other material shall be applied to the faces of form work in contact with wet concrete to prevent adherence of the concrete.

- **Proportions of Concrete:** The aggregate shall be measured by volume (unless instructed to be measured by weight) in approved containers which shall be filled without compacting, accurate allowance being made for bulking due to moisture in the fine aggregate. Cement, if stored in bags, one or more complete bags (50 kg each bag. According to available mixing, distributing and compacting arrangements) shall be used for each batch of concrete. Cement, if stored loose, it shall be measured by weight. The proportion of cement and aggregate shall be as described on the drawing or else where.

Only sufficient water shall be added to cement and aggregate during mixing to produce a concrete having sufficient workability to enable it to be well consolidated, to be worked into the corners of form work and around the reinforcement, to give the specified surface finish and to have specified strength through out the work. Slump test shall be conducted from time to time to ensure the maintenance of desired consistency.

- **Mixing of concrete:** The aggregate and cement shall be thoroughly mixed together in the specified proportions in a batch type mechanical mixer. Water shall not be admitted to the drum of the mixer until all cement and aggregate, constituting the batch are in the drum.
- **Distribution of Concrete:** Concrete shall be distributed from mixer to the position of placing in the works by means which do not cause separation or otherwise impair the quality of the concrete. The equipment shall be kept free from set concrete.
- **Placing of concrete:** Before proceeding to place the concrete, the form work shall be realigned if necessary and water and rubbish therein shall be removed. Immediately prior to the placing of concrete, the form work shall be well wetted except in frosty weather.

Each layer of concrete while being placed shall be consolidated by mechanical vibration and tamping to form a dense material, free from honey combing, free from water and air holes.

Concrete shall be placed in a single operation to a full thickness of slab, beams etc and shall be placed in horizontal layers not exceeding 1m deep in walls and columns etc., If stopping of concrete operation is unavoidable else where, a construction joint shall be made here the concrete work is stopped.

- **Sealing Mortar:** the sealing mortar for packing of recesses, seal grooves and form holes shall consist of one part of cement and 1 ½ parts of the sand by weight. For tie holes and pipe seals, the mortar shall be packed tightly into place.
- **Seal around pipes:** Pipes shall not be run through the wall except where absolutely necessary. Grooves shall be provided around each pipe where it intersects exposed surface, and shall be filled with sealing mortar.
- **Placing of Concrete Joints:** Construction joints shall be rebated and shall be vertical and horizontal, as required and shall be at right angle to the axis of member. Construction joints shall be in a position described on the drawings and where not so described shall be in accordance with the following

A joint shall be formed horizontally at the top of a foundation 75mm below the lowest soffit of the beams meeting at the head of a column. A joint shall be formed in the rib of a large T- beam and L- beam 25mm below the soffit of the slab.

Concrete in the beam shall be placed without a joint but if it is unavoidable, the joint shall be vertical and at the middle of a span. A joint in a slab shall be vertical and at the middle of a span, parallel to the principal reinforcement and where it is unavoidable at right angle to the principal reinforcement.

Before placing new concrete against the concrete that has already hardened, the face of the old concrete shall be cleaned and roughened and scum and loose aggregate removed there from and immediately before placing the new concrete the face shall be thoroughly wetted and coating of neat cement grout applied thereto.

Protection of concrete and curing: Newly placed concrete shall be protected by approved means from frost, rain, sun and drying winds. Exposed faces of concrete shall be kept moist for atleast seven days after placing except where there is a likely hood of curing water or damp covering freezing.

Concrete placed below ground level shall be protected from falling earth during and after placing. Immature concrete should be protected from damage by debris, ice, excessive loading, vibration, abrasion, deleterious ground water, floatation and other influences that may impair the durability and strength of the concrete.

Spring of Form Work: Form work shall be removed by gradual easing. Removal of form work shall proceed only in the presence of competent person. A complete record of the dates upon which the concrete is placed in each part of the work and the date upon which the formwork is removed there from, shall be maintained. Before the bottom forms and posts are removed, the concrete surface should be exposed in order to ascertain that the concrete has sufficiently hardened. Where impossible the form work should be left longer as it would assist curing.

Finishes: Honey combed surfaces shall be made good immediately upon removal of form work and superficial water and air holes shall be filled in. No other finish to the concrete shall be given unless it is inspected by the Engineer-in-Charge.

13.7. Water Tightness Test for Hydraulic Structures

After completion of the hydraulic structure, it is tested for water tightness. If there is more than one compartment, initially all of them are filled in simultaneously. This ensures uniform settlement all over the area. The filling operations are also carried out gradually and full supply level is reached in a period of not less than 72 hours

Indian Standard 3370 (Part-I General requirements) 'Code of Practice for the Concrete Structures for Storage of Liquids' specifies water tightness test at full supply level as described below:

In case of tanks where external faces are exposed, such as Over head tanks, the requirement of the test shall be deemed to be satisfied in the external faces show no signs of leakage and remain apparently dry over a period of observation of seven days, after allowing seven days period for absorption after filling.

In case of tanks whose external faces are submerged and are not accessible for inspection such as underground tanks, the tanks shall be filled with water and after the expiry of seven days after filling; the level of the surface of water shall be recorded. The level of the water shall be recorded again at subsequent intervals of 24 hours over a period of seven days. The total drop in the surface level over a period of seven days shall be taken as an indication of the water tightness

of the tank. The Engineer-in-Charge shall decide the actual permissible nature of this drop in the surface level, taking into account whether tanks are open and the corresponding drop it has on evaporation losses. For many purpose, however, under-ground tanks whose top is covered may be deemed to be water tight if the total drop in the surface level over a period of seven days does not exceed 40mm.

If the structure does not satisfy the conditions of the test and the daily drop in water is decreasing, the period of test may be extended for further seven days and if specified limit is then reached, the structure may be considered as satisfactory.

13.8. Brick Work

Bricks shall be table moulded whole, sound and well burnt, free from cracks, to ring when struck and not to crack or break when soaked in water and rectangular in shape and uniform in size. No bricks which absorb water more than 1/5th of their own weight when dry shall be used. Bricks shall be clean well wetted or soaked in fresh water for at least twenty-four hours before use on the work and no brickbats or broken bricks shall be used except where absolutely necessary to complete the bond. Entire cut bricks wherever specified shall be used and shall be of the first quality.

The brickwork shall be constructed in cement mortar (1:4) or (1:6) or as specified in the drawing, to the full height, length and thickness as shown on the drawings. The cement mortar shall be carefully mixed and used, stiff and not dry. A good bond should be preserved through out the work both laterally and transversely. All bed joints shall be perpendicular to the pressure upon them that is horizontal in vertical walls, radial in arches, and at right angles to the sloe in battering walls, if any. In walls the courses shall be kept perfectly horizontal and to plumb. The vertical joints shall have break with course immediately below or above, but they shall be directly over another in alternate courses to prevent the necessity of brick bats. The joints shall be done in regular height of about 0.9 m a day and not in a haphazard way. All masonry shall be kept wet for at least fourteen days after its completion. The joints in brick work of all walls which are to be plastered shall be raked out about 10 mm in depth as the work proceeds.

Preparing Surfaces for plastering:

Immediately prior to the application of the plaster, the joints of the brickwork shall be raked out to a depth of at least 12 mm and the surface cleared and thoroughly saturated with water before the plastering is commenced.

Cement Plaster

Cement plaster shall be of the specified composition cement and mortar. Plaster shall be laid in a single coat of somewhat more than the required thickness and shall be leveled with a flat wooden straight edge and smothered with proper trowels to the precise thickness required. The plastering shall be kept thoroughly wet for seven days from the date it is done. The entire finished plaster work shall be to perfect plumb.

Rough and Fine Sand Plaster (in two coats)

Rough and fine sand plaster shall be made by mixing one part of cement to five parts of clean, fine sand for first coat, the ingredients shall be first mixed dry and then mixed with fresh clean water, till a satisfactory and workable mix is obtained. The plastered surface while being completed shall be left rough by wire brush to receive the second and finishing coat of plaster.

The second coat shall be made by mixing the second and finishing coat of plaster. The second coat shall be made by mixing one part of cement to two parts of clean, very fine sand and water in a similar way as first coat, and after being applied, shall be worked all over the surface by means of sponges to obtain an even and granular surface all over. The entire plaster work shall be to perfect plumb. The sides of window openings such as jambs and reveal sun breakers, drop pardas, chajjas and the like around externally, shall be finished properly.

Curing

The plaster shall be thoroughly cured for 15 days. Any cracks, which appear in the surface and all portions which sound hollow when tapped or are found to be soft or otherwise defective, shall be cut out in rectangular shape and redone.

13.9. Form Work

The form work shall conform to the shape, lines and dimensions as shown in the plans and be so constructed as to remain sufficiently rigid during the lacing the compacting of the concrete, and shall be sufficiently tight to prevent loss of liquid from the concrete.

Stripping Time

In no circumstances shall form be struck until the concrete reaches strength of at least twice the stress to which the concrete may be subjected at the time of striking. The strength referred to shall be that of concrete using the same cement and aggregates, with the same proportions, and cured under conditions of temperature and moisture similar to those existing in the work. Where possible, the form work should be left longer, as it would assist the curing.

In normal circumstances (generally where temperatures are above 20°C.) where ordinary cement is used, forms may be struck after expiry of the following periods.

- | | |
|-------------------------------------|--------------|
| a. Walls, columns and verticals | 24 to 48 hr. |
| b. Slabs (props left under) | 3 days |
| c. Beams soffits (props left under) | 7 days |
| d. Removal of props to slabs: | |
| 1. Spanning upto 4.5m | 7 days |
| 2. Spanning over 4.5 m | 14 days |
| e. Removal of props under beams | |
| And arches | |
| 1. Spanning upto 6m | 14 days |
| 2. Spanning over 6 m | 21 days |

Procedure When Removing the Form Work

All form work shall be removed without such shock or vibration as would damage the reinforcement concrete. Before the soffit and struts are removed the concrete surface shall be exposed where necessary, in order to ascertain that the concrete has sufficiently hardened. Proper precautions shall be taken to allow for the decrease in the rate of hardening that occurs with all cements in the cold weather.

13.10. Centering

The term “centering” shall include all forms and moulds, sheeting, shuttering planks, poles, posts, shores, struts, ties and uprights and all over temporary, supports to the concrete during the process of setting.

The centering shall be such dimension and so constructed as to remain rigid during the laying, tamping and setting of the concrete. The joints must be tight so as to prevent leakage of the liquid cement. The centering must be arranged so that the portion below the slabs can be removed first, then the sides of beams and finally that below the beams.

All faces, which will come in contact with the cement concrete in beams and slabs, pillars, must be with steel plates or plank centering only and should be non absorbent type. Mud centering or spilt bamboo shall not be permitted.

Reinforcement shall be bent in accordance with procedure specified in IS-2052/1963, Code of Practice for bending and fixing of Bars for concrete reinforcement and shall not be straightened in a manner that will injure the material.

All reinforcement steel shall be accurately located in the forms, and firmly held in place, before and during the placing of concrete, by means of chairs and other devices. Reinforcement shall be tied at intersections with 18 gauge.

13.11. Pipelines

Laying, jointing of Pipelines and Testing of Pipelines- General principles

Before laying the pipes, the detail map of the area showing the alignment, sluice valves, scour valves, air valves and fire hydrants along with the existing intercepting sewers, telephone and electric cables and gas pipes will have to be studied. Care should be taken to avoid damage to the existing sewer, telephone and electric cables and gas pipes. The pipeline may be laid on the side of the street where the population is dense. Pipes are laid underground with a minimum cover of one meter on the top of the pipe. In special case such as in hilly and valley area pipelines are laid above ground, then the pipelines must be laid on a compacted base or by providing masonry pedestals.

a) Excavation of trenches

Excavation may be done manual or by machine. The trench shall be so dug that the pipe may be laid to the required gradient and at the required depth. When the pipeline is under road way a minimum cover of 1.0 m is recommended. The width of the trench at bottom shall provide not less than 200 mm clearance on both sides of the pipe. Additional width shall be provided at positions of sockets and flanges for jointing. Depths of pits at such places shall also be sufficient to permit finishing of joints.

b) Handling of Pipes

While unloading pipe shall not be thrown down but may be carefully unloaded on inclined timber skids. Pipes shall not be dragged over other pipes and along concrete and similar pavements to avoid damage to pipes

c) Detection of Cracks and Pipes:

The pipes and fittings shall be inspected for defects and be rung with a light hammer, preferably while suspended, to detect cracks. Smearing the outside with chalk dust helps in the location of cracks. If doubt persists further confirmation may be obtained by pouring a little kerosene on the inside of the pipe at the suspected spot. If a crack is present the kerosene seeps through and shows on the outer surface. Any pipe found unsuitable after inspection before laying shall be rejected.

d) Lowering of Pipes and Fittings:

All pipes, fittings, valves and hydrants shall be carefully lowered into the trench by means of derrick, ropes or other suitable tools and equipment to prevent damage to pipe materials and protective coatings and linings. Pipes over 300 mm dia shall be handled and lowered into trenches with the help of chain pulley blocks.

e) Cleaning of Pipes and Fittings:

All lumps, blisters and excess coating material shall be removed from socket and spigot end of each pipe and outside of the spigot and inside of the socket shall be wire-brushed and wiped clean and dry and free from oil and grease before the pipe is laid.

f) Depth of cover

The pipeline shall be protected against damages due to external influence. Hence, the pipeline shall not be laid at surface; they shall be laid at sufficient depths to avoid damage by superimposed load. When heavy traffic is anticipated, depth of cover has to be worked out after taking into consideration the structural and other aspects. However in narrow streets 1-1.5 mt wide where no vehicular traffic is expected and digging deep may cause danger to the stability of adjoining structures it may be reduced to 60 cm. Distribution mains and pumping mains can be laid along the road berm to avoid load due to vehicular traffic on the pavement of road. When road is to be crossed, GI/CI pipes are preferred to PVC Pipes.

g) Hydraulic testing of the pipeline

After a new pipeline is laid, hydrostatic test shall be done to ensure that pipes and joints are sound enough to withstand the maximum pressure likely to be developed under working conditions.

The completed pipeline may be tested either in one length or in sections. Each section should be properly sealed off with special stop ends and secured by adequate temporary anchors. All permanent anchors should be in position and concrete should develop adequate strength before the commencement of test. The section under test should be filled with water, taking care that all the air is displaced either through vents at the high points or by using a peg or a sphere.

In a pumping main the total head for which the pump to be designed is the maximum working pressure. However, in the case of submersible pumps, by the time water comes out of the pump up to the ground level near the bore well the total head will be reduced by the depth of water in the bore well. Hence, PVC Pipes at the bore well location shall withstand a resulting static head above ground level plus the head due to water hammer effect. In gravity main the maximum static head is equal to the hydraulic gradient line minus the lowest ground level along the alignment of the pipeline.

The test pressure for pipelines shall be as per following:

Pumping Mains = 50% of Pipe test pressure class or working pressure which ever is higher

Gravity Lines = 2/3 rd of the pipe test pressure or working pressure which ever is higher

After filling the pipeline should be pressurized to the specified operating pressure and left for a period of time to achieve stable conditions. The pipeline is pressurized up to the full test pressure gradually and the section under test completely closed. The test should be mentioned for a period not less than 10 minutes to reveal any defects in the pipes, joints or anchorage. The test pressure should be measured at the lowest point of the section under test or alternatively, an allowance should be made for the static head between lowest point and the

point of measurement, to ensure that the required test pressure is not exceeded at the lowest point.

The leakages / burst if any should be identified and rectified there after the test is again carried out.

h) Testing of the Pipeline

After laying and jointing, the pipeline must be pressure tested to ensure that pipes and joints are sound enough to withstand the maximum pressure likely to be developed under working conditions.

Testing of Pressure Pipes

The field test pressure to be imposed should be not less than the maximum of the following:

- (a) 1 ½ times the maximum sustained operating pressure.
- (b) 1 ½ times the maximum pipeline static pressure.
- (c) Sum of the maximum sustained operating pressure and the maximum surge pressure.
- (d) Sum of the maximum pipeline static pressure and the maximum surge pressure, subject to a maximum equal to the work test pressure for any pipe fittings incorporated.

The field test pressure should wherever possible be not less than 2/3 work test pressure appropriate to the class of pipe except in the case of spun iron pipes and should be applied and maintained for at least four hours. If the visual inspection satisfies that there is no leakage, the test can be passed.

Where the field test pressure is less than 2/3 work test pressure, the period of test should be increased to at least 24 hours. The test pressure shall be gradually raised at the rate of 1 kg/cm²/min. If the pressure measurements are not made at the lowest point of the section, an allowance should be made for the difference in static head between the lowest point and the point of measurement to ensure that the maximum pressure is not exceeded at the lowest point. If a drop in pressure occurs, the quantity of water added in order to re-establish the test pressure should be carefully measured. This should not exceed 0.1litre per mm of pipe diameter per KM of pipeline per day for each 30 meter head of pressure applied.

In case of gravity pipes, maximum working pressure shall be 2/3rd work test pressure. The allowable leakage during the maintenance stage of pipes carefully laid and well tested during construction however should not exceed;

$$qL = \frac{ND\sqrt{P}}{115}$$

where,

qL = Allowable leakage in cm³/hour

N = No of joints in the length of pipe lines

D = Diameter in mm

P = The average test pressure during the leakage test in kg/cm²

Where any test of pipe laid indicates leakage greater than that specified as per the above formula, the defective pipe(s) or joint(s) shall be repaired /replaced until the leakage is within the specified allowance. The above is applicable to spigot and socket Cast Iron pipes

and A.C. pressure pipes, whereas, twice this figure may be taken for steel and prestressed concrete pipes.

Testing of Non-Pressure Conduits:

In case of testing of non-pressure conduits, the pipeline shall be subject to a test for of 2.5 meters head of water at the highest point of the section under test for 10 minutes. The leakage or quantity of water to be supplied to maintain the test pressure during the period of 10 minutes shall not exceed 0.2litres/mm dia of pipes per kilometer/length/per/day.

Laying and jointing system of cast iron pipes

Laying and jointing system of cast iron pipes shall conform IS-3114(1985) Code of practice for laying of cast iron pipes.

a) Excavation and preparation of trenches

The trench shall be so dug that the pipe may be laid to the required alignment and at a required depth. When the pipeline is under roadway, a minimum cover of 1.0 m is recommended for adoption but it may be modified to suit local conditions.

b) Width of trench: The width of trench at the bottom shall be such as to provide not less than 20 cm clearance on the either side of pipe.

Additional width shall be provided at positions of sockets and flanges for jointing to be made properly. Depth of pits at such places shall also be sufficient to permit finishing of joints.

c) Trimming of trench bottom: before laying the pipe, bottom of pipe trench shall be properly trimmed off to present a plain surface and all irregularities shall be leveled. Where rock or boulders are encountered, the trench shall be trimmed to a depth of atleast 8 cm below the level at which the bottom of barrel of the pipe is to be laid, and filled to a like depth with stones broken to pass through a sieve of 12.5mm aperture size and well rammed to form a fair and clean bed for pipes.

d) Unloading of pipes: While unloading, pipes shall not be thrown down from the trucks on hard roads. In order to avoid damage to the pipes on hard roads. In order to avoid damage to the pipes and especially to the spigot ends, pipes should not be dragged along concrete and similar pavements with hard surfaces.

e) Lowering of pipes and fittings: All pipes, fitting, valves and hydrants shall be carefully lowered into trench, piece by piece by means of a derrick, or ropes or other suitable tools or equipment so as to prevent damage to pipes, fittings, protective coating sand linings. Pips over 300 mm dia shall be handled and lowered into trenches with the help of chain pulley blocks.

The pipes shall be inspected for defects, by ringing with a light hammer preferably while suspended to detect cracks. If double persists, further confirmation may be obtained by passing a little kerosene which seeps through and shown on the outer surface. Any pipe found the unsuitable after inspection before laying shall be rejected.

cleaning of pipes and fittings: The outside of the spigot and inside of the socket shall be wire brushed and wiped clean and dry and free from oil and grease before pipe is laid.

f) Laying pipe: Every precaution shall be taken to prevent foreign material from entering the pipe while it is being placed in the line. During laying operation, no debris, tools, clothing or other materials shall be placed in the pipe.

After placing a length of pipe in the trench, the spigot shall be centered in the socket and the pipe forced home and aligned to the gradients. At times when pipe laying is not in progress, the open ends of the pipes shall be closed by water tight plugs.

- g) Cutting of pipes: The cutting of pipe for inserting valves, fittings or closure pieces shall be done in a neat and workman like manner, so as to leave a smooth and a right angle to the axis of the pipe. For this purpose use of pipe cutting machine is recommended. The electric arc cutting machine may be permitted using a carbon or steel rod. Flame cutting by means of an oxyacetylene torch shall not be followed.
- h) Direction of Laying of Socket End: On level ground, the socket ends should face upstream. When the line runs uphill, the socket ends should face the upgrade.
- i) Permissible Deflection in joints: The deflection allowed at joints shall not exceed 2.5° for lead joints and in case of rubber joints for 80-300mm dia 5° and 450mm to 750mm dia 4° .
- j) Usage of Anchor and Thrust Blocks in pipeline: Thrust blocks suitably designed shall be provided wherever necessary to transmit hydraulic pressure. Where hydraulic thrust is in an upward direction, anchor blocks of sufficient height shall be provided to which the pipes shall be secured with steel straps.
- k) Jointing system

Following are the type of joints employed in cast iron pipes.

1. Spigot and Socket joints: IS- 3114, Code of Practice for laying of cast iron pipes provides the following types of joints:
 - Molten lead (under dry conditions)
 - Cement joints
 - Lead wool (under dry conditions)
 - Tyton joints
 - Push-type joints

2. Flanged joints.

- l) Testing of pipe line:

After laying and jointing, pipe line must be pressure tested to ensure that pipe line joints are sound enough to withstand maximum pressure likely to be developed under working conditions. The full test imposed should not be less than the following:

- 1.5 times the maximum sustained operating pressure
- 1.5 times the maximum pipe line static pressure
- Sum of the maximum sustained operating pressure and the maximum surge pressure.
- Sum of the pipe line static pressure and the maximum surge pressure subject to a maximum equal to works test pressure for any pipe fitting incorporated.

The leakage should exceed 0.1 liter per mm of pipe dia per KM of pipeline per day for each 30 m head of pressure applied. When a pressure drop occurs, the quantity of water added in order to re establish the test pressure should be carefully measured which amounts to leakage.

Cast iron specials for mechanical and push-on flexible joints for pressure pipe lines for water gas and sewage (IS 13382 – First Revision). This standard covers requirement for cast iron special castings to be used with cast iron and ductile iron pressure pipes for carrying water, gas and sewage,. This standard is applicable to fittings meant for mechanical joints (bolted glands) push on joints (single rubber gaskets and flanged joints).

Laying and jointing of ductile iron pipes: (IS 12288-1987)

a) Excavation and preparation of trenches

The trench shall be so dug that the pipe may be laid to the required alignment and at a required depth. When the pipeline is under roadway, a minimum cover of 1.0 m is recommended for adoption but it may be modified to suit local conditions.

b) Cutting

Abrasive cutting discs by angle grinders available are electrically operated (single phase AC). The discs made of silicon carbide have been found to be most suitable for D.I pipes with cement mortar lining.

c) Gasket

The quality of rubber gasket is governed by IS -5382. The gasket has two sections of different hardness. Harder retaining heel of the gasket locks it in place and softer bulb gives the positive seal. By pushing the spigot in to the socket, the bulb is compressed to give a permanent water tight joint.

Laying of Pipes and Specials

Before being laid the pipes shall be examined to see that there are no cracks or defects. Subject to approval by engineer who is supervising the job damaged position of the cracked pipe may be cut at a point not less than 15 cm. beyond the visible extremity of the crack. The pipes shall be thoroughly cleaned of all dust and dirt and special care shall be taken to clean the inside of the socket and outside of the spigots.

The pipes shall be lowered into the trench by means of suitable pulley blocks, sheet legs, chains ropes etc. In no case the pipes shall be rolled and dropped into the trench. After lowering, the pipes shall be arranged so that the spigot of one pipe shall be carefully centered into the socket of the next pipe, and pushed to the full distance that it can go. The pipeline shall be laid to the levels required. Specials shall also be laid in their proper position as Stated above.

Where so directed, the pipes and specials may be laid on masonry or concrete pillars. The pipe laid on the level ground, shall be laid with socket facing the direction of the flow of water. In all other cases, the sockets shall be laid facing up hill.

Any deviation either in plan or elevation less than $11\frac{1}{4}$ degree shall be effected by laying the straight pipes round a flat curve, of such radius that minimum thickness of lead at the face of the socket shall not be reduced below 6 mm. or the opening between spigot and socket increased beyond 12 mm at any point. A deviation of about $2\frac{1}{4}$ degree can be affected at each joint in this way. At the end of each day's work, the last pipe laid shall have its open ends securely closed with a wooden plug to prevent entry of water, soil, rats and any other foreign matter into the pipe.

Cement concrete thrust blocks of suitable design shall be provided at 45^0 and 90^0 bands of the pipes and also at places where there is likelihood of thrust so as to withstand the dynamic and static forces developed due to water in the pipe line. The thrust blocks shall be made after the joints have been made.

Jointing

Jointing shall be carried out by bolting the flanges (in case of flanged pipes) of the adjacent pipes using approved quality rubber gaskets that is confirming to IS-12820-1989. In case of Socket spigot pipe jointing shall be using rubber ring (tyton joint).

- For DN 600 to DN 1600 it is preferable to loop the gasket into the shape of a cross for insertion. Apply radial pressure to the gasket at the hard shaped loop to force it into the place.
- Apply thin film of lubricant to the inside surface of the gasket and to the outside surface of the spigot. Support pipe or fitting just clear off the trench bottom and enter spigot into the socket until contact is made

Testing of Joints

After laying and jointing, the pipes and fittings shall be inspected under working conditions of pressure and flow. Any joint found leaking shall be redone and all leaking pipes removed and replaced without extra cost.

The pipes and fittings after they are laid shall be tested to hydraulic pressure of 6 kg/sq.cm (60 metre or double the designed working pressures whichever is more). The pipes shall be slowly and carefully charged with water allowing all air to escape and avoiding all shock water hammer.

The draw off takes and stopcocks shall then be closed and specified hydraulic pressure shall be applied gradually. Pressure gauge must be accurate and preferably should have been recalibrate before the test. The test pressure should maintain without loss for at least half an hour. The pipes and fittings shall be tested in sections as the work of laying proceeds, keeping the joints exposed for inspection during the testing.

Steel Pipes

Laying and Jointing (IS 1978-1982),(IS -1979)(IS -5822/1994)(IS 3589)

Trench When the pipe is under road way a minimum cover of 1m is recommended. The width of the trench at the bottom shall be such has to provide not less than 20 cm clearance on either side of the pipe

Pits for the joints :When the welding is to be carried out with the pipe in the trench additional excavation of not more than 60 cm in depth and 90 cm in length should be provided all-round the pipe at the portion of the joints for facility of welding

Laying: While laying, the pipes already stocked along the trenches are lowered down into the trenches with the help of chain pulley block. The formation of bed should be uniform. The pipes are laid true to the alignment and gradient before jointing. The ends of these pipes are butted against each other, welded and a coat of rich cement mortar is applied after welding. Steel pipes may be joined with flexible joints or welding but lead or other filler does not recommend joints, hot or cold. The welded joint is to be preferred. In areas prone to subsidence this joint satisfactory but flexible joints must be provided to isolate valves and branches.

When welding is adopted, plain-ended pipes may be jointed by butt welds or sleeved pipes by means of fillet welds. For laying long straight length of pipelines, butt joint technique may be employed. The steel pipes used for water supply include hydraulic lap welded, electric fusion welded, submerged arc welded and spiral welded pipes. The latter are being made from steel strip. For laying of welded steel pipe I.S. 5822-1986 may be referred to. For hydraulic testing of steel pipelines, the procedure described for cast iron spun pipes and ductile iron pipes may be followed.

Expansion Joints: For all pipe lines laid above ground provision of expansion and contraction on account of temperature variation should be made by providing expansion joints at pre-determined intervals

Testing: The pipe line after laying should be tested for every 500 mts of length or at intervals suggested by the department. The field test pressure to be imposed should not be less than greatest of the following

- a. One time the maximum sustained pressure
- b. One time Maximum pipeline static pressure
- c. Sum of the maximum static pressure and surge pressure subject to test pressure

When the field test pressure is less than two-thirds test pressure, the period of test should be atleast 24 hrs.

The drop in pressure occurs, the quantity of water added in order to reestablish the test pressure should be carefully measured. This should not exceed 0.1 litre per mm of pipe dia per KM of pipeline per day for each 30 mt. of head applied

Asbestos Cement Pipe

Laying and Jointing (IS 1592-1989)

The width of the trench should be uniform throughout the length and greater than the outside diameter of the pipe by 300mm on either side of the pipe. The depth of the trench is usually kept 1 meter above the top of the pipe. For heavy traffic, a cover of atleast 1.25 meter is provided on the top of the pipe.

The AC pipes to be laid are stacked along the trenches on the side or opposite to the spoils. Each pipe should be examined for any defects such as cracks, chipped ends, crusting of the sides etc. The defective pipes should be removed forthwith from the site as otherwise have to be cleaned. The lighter pipes weighing less than 80Kg can be lowered in the trench by hand. If the sides of the trench slope too much, ropes looped around both the ends. One end of the rope is held by men and is slowly released to lower the pipe into the trench. After their being lowered into the trench they are aligned for jointing. The bed of the trench should be uniform.

Pipe Joints

These are two types of joints for AC pipes.

- Cast iron detachable joint, (CID) and
 - AC coupling joint.
- A. Cast Iron Detachable Joints: This consists of two cast iron flanges, a cast iron central collar and two rubber rings along with a set of nuts and bolts for the particular joint. For this joint, the AC pipes should have flush ends. For jointing a flange, a rubber ring and a collar are slipped to the first pipe in that order; a flange and a rubber ring being introduced from the jointing of the next pipe. Both the pipes are now aligned and the collar centralized and the joints of the flanges tightened with nuts and bolts.
 - B. A.C. Coupling Joint: This consists of an A.C. coupling and three special rubber rings. The pipes for these joints have chamfered ends. These rubber rings are positioned in the grooves inside the coupling, then grease is applied on the chamfered end and the pipe and coupling is pushed with the help of a jack against the pipe. The mouth of the pipe is

then placed in the mouth of the coupling end and then pushed so as to bring the two chamfered ends close to each other. Wherever necessary, change over from cast iron pipe to AC pipes or vice-versa should be done with the help of suitable adapters. I.S. 6530-1972 may be followed for laying A.C. pipes.

Pressure Testing

The procedure for the test as adopted is as follows:

- At a time one section of the pipeline between two sluice valves is taken up for testing. The section usually taken is about 500 meters long.
- One of the valves is closed and the water is admitted into the pipe through the other, manipulating air valves suitably.

(If there are no sluice valves in between the section, the end of the section can be sealed temporarily with an end cap having an outlet which can serve as an air relief vent or for filing the fine as may be required. The pipeline after it is filled, should be allowed to stand for 24 hours before pressure testing)

- After filling, the sluice valve is closed and the pipe section is isolated.
- Pressure gauges are fitted at suitable intervals on the crown into the holes meant for the purpose.
- The pipe section is then connected to the delivery side of a pump through a small valve.
- The pump is then operated till the pressure inside reaches the designed value which can be read from the pressure gauges fixed
- After the required pressure has been attained, the valve is closed and the pump disconnected.
- The pipe is then kept under the desired pressure during inspection for any defect, i.e. leakages at the joints etc. The test pressures will be generally as specified IS code. The water will then be emptied through scour valves and defects observed in the test will be rectified.
- As far as possible, pipes may be buried for short distances provided adequate protection is given against damage and where so required special care to be taken at joints.

Laying and Jointing of G.I Pipes

Galvanized iron pipes shall be jointed with threaded and socket joints, using threaded fittings. Care shall be taken to remove any burr from the end of the pipes after threading. White lead or an equivalent jointing compound of proprietary make shall be used, according to the manufacturer's instructions. Compounds containing red lead shall not be used because of the danger of contamination of water. Any threads exposed after jointing shall be painted with bituminous paint to prevent corrosion. The joint shall be allowed to cool without disturbance.

Concrete Pipes

Laying and Jointing(IS -783/1991)

The concrete pipes should be carefully loaded, transported and unloaded avoiding impact. The use of inclined planes or chain pulley block is recommended. Free working

space on either side of the pipe shall be provided in the trench which shall not be greater than $\frac{1}{3}$ the dia of the pipe but not less than 15cm on either side.

Laying of pipes shall proceed upgrade of a slope. If the pipes have spigot and socket joints the socket ends shall face upstream. The pipes shall be joined in such a way to provide as little unevenness as possible along the inside of the pipe. Where the natural foundation is inadequate, the pipes shall be laid in a concrete cradle supported on proper foundation or any other suitably designed structure. If a concrete cradle is used, the depth of concrete below the bottom of the pipes shall be at least $\frac{1}{4}$ the internal diameter of pipe with the range of 10-30 cm. It shall extend up to the sides of the pipe at least to a distance of $\frac{1}{4}$ the dia for larger than 300mm. The pipe shall be laid in the concrete bedding before the concrete has set.

Trenches shall be back filled immediately after the pipe has been laid to a depth of 300mm above the pipe subject to the condition that the jointing material has hardened (say 12 hours at the most). The backfill material shall be free from boulders, roots of trees etc. The tamping shall be by hand or by other hand operated mechanical means. The water content of the soil shall be as near the optimum moisture content as possible. Filing of trench shall be carried on simultaneously on both sides of the pipe to avoid development of unequal pressures. The back fill shall be rammed in 150mm layers upto 900 mm above the top of the pipe.

Joints may be of any of the following types

- Bandage joint
- Spigot and socket joint (rigid and semi-flexible)
- Collar joint (rigid and semi-flexible)
- Flush joint (internal and external)

In all pressure pipelines, the recesses at the ends of the pipe shall be filled with jute braiding dipped in the hot bitumen. The quantity of jute and bitumen in the ring shall be just sufficient to fill the recess in the pipe when pressed hard by jacking or any other suitable method.

The numbers of pipes that shall be jacked together at a time depend upon the dia of the pipe and the bearing capacity of soil. For small pipe up to 250mm dia, six pipes can be jacked together at a time. Before and during jacking, care should be taken to see that there is no offset at the joint. Loose collar shall be set up over the joint so as to have an even caulking space all round and into this caulking space shall be rammed a 1 : 1.5 mixture of cement and sand just sufficiently moistened to hold together in the form of a cold when compressed in the hand. The caulking shall be so firm that it shall difficult to drive the point of a penknife into it. The caulking shall be employed at both the ends in a slope of 1:1. In the case of non-pressure pipes the recess at the end of the pipes shall be filled with cement mortar 1:2 instead of jute braiding soaked in bitumen. It shall be kept wet for 10 days for maturing.

Pressure Test

When testing the pipelines hydraulically, the line shall be kept filled completely with water for a week. The pressure shall then be increased gradually to full test pressure as explained in para and maintained at this pressure during the period of the with permissible allowance indicated therein. For further details, reference may be made to I.S. 458-1971.

Pre-stressed Concrete Pipes

Laying and Jointing

PSC pressure pipes are provided with flexible joints, the joints being made by the use of rubber gasket. They have socket spigot ends to suit the rubber ring joint. The rubber gasket is intended to keep the joint water tight under all normal conditions of service including expansion, contraction and normal earth settlement. The quality of rubber used for the gasket should be waterproof, flexible and should have a low permanent set. Refer to IS 784-1978, for laying of PSC pipes.

Pressure testing

Testing of PSC pipe is the same as given for CI Pipes. However the quantity of water added in order to re-establish the test pressure should not exceed 3 liters (instead of 0.1 liters) per mm dia, per km per 24 hours per 30m head for non absorbent pipes as per the IS 783 .

Plastic Pipes

Plastic pipes are produced by extrusion process followed by calibration to ensure maintenance of accurate internal diameter with smooth internal bores. These pipes generally come in lengths of 6 meters. A wide range of injection moulded fittings, including tees, elbows, reducers, caps, pipe saddles, inserts and threaded adapters for pipe sizes up to 200mm are available.

PVC PIPES

Precautions in Handling and Storage

Because of their lightweight, there may be a tendency for the PVC pipes to be thrown much more than their metal counterparts. This should be discouraged and reasonable care should be taken in handling and storage to prevent damage to the pipes. On no account should pipes be dragged along the ground. Pipes should be given adequate support at all times. These pipes should not be stacked in large piles, especially under warm temperature conditions, as the bottom pipes may be distorted thus giving rise to difficulty in pipe alignment and joining. For temporary storage in the field, where racks are not provided, care should be taken that the ground is level, and free from loose stones. Pipes stored thus should not exceed three layers and should be so stacked as to prevent movement. It is also recommended not to store one pipe inside another. It is advisable to follow the practices mentioned as per IS 4985-1981 and IS 7634-Part I.

Laying and Jointing

The trench bed must be free from any rock projections, the trench bottom where it is rocky and uneven a layer of sand or alluvial earth equal to $1/3^{\text{rd}}$ dia of pipe of 100mm whichever is less should be provided under the pipes.

The trench bottom should be carefully examined for the presence of hard objects such as flints, rock, projections or tree roots. In uniform relatively soft fine grained soils found to be free of such objects and where the trench bottom can readily be brought to an even finish providing a uniform support for the pipes over their lengths, the pipes may normally be laid directly on the trench bottom. In the other cases, the trench should be cut correspondingly deeper and the pipes laid on a prepared under bedding, which may be drawn from excavated material if suitable.

As a rule, trenching should not be carried out too far ahead of pipe laying. The trench should be as narrow as practicable. This may be kept from 0.30m over the outside diameter of pipe and depth may be kept at 0.60 – 1.0m depending upon traffic conditions. Pipe lengths are placed end to end along the trench. The glued spigot and socket jointing techniques as mentioned later is adopted. The jointed lengths are then lowered in the trench and when sufficient length has been laid, the trench is filled.

If trucks, lorries, or other heavy traffic will pass across the pipeline, concrete tiles 600 x 600mm of suitable thickness and reinforcement should be laid about 2m above the pipe to distribute the load. If the pipeline crosses a river, the pipe should be buried at least 2m below bed level to protect the pipe.

For bending, the cleaned pipe is filled with sand and compacted by tapping with wooden stick and pipe ends plugged. The pipe section is heated with flame and the portion bent as required. The bend is then cooled with water, the plug removed, the sand poured out and the pipe (bend) cooled again. Heating in hot air over hot oil bath, hot gas or other heating devices are also practiced. Joints may be welded, or flamed or with rubber gaskets or made with solvent cement. Threaded joints are also feasible but are not recommended.

Jointing of PVC pipes can be made in following ways:

- 1) Solvent cement
- 2) Rubber ring joint
- 3) Flanged joint
- 4) Threaded joint

For further details on laying & jointing of PVC pipes, reference can be made to IS 4985 – 1988, IS 7634 – Part 1-3.

Socket and spigot joint is usually preferred for all PVC pipes upto 150mm in dia. The socket length should at least be one and half time the outer dia for sizes upto 100mm dia and equal to the outer dia for larger sizes.

For pipe installation, solvent gluing is preferable to welding. The glued spigot socket connection has greater strength than can ever be achieved by welding. The surface to be glued are thoroughly scoured with dry cloth and preferably chamfered to 30°. If the pipes have become heavily contaminated by grease or oil, methylene cement is applied with a brush evenly to the outside surface of the spigot on one pipe and to the inside of the socket on the other. The spigot is then inserted immediately in the socket upto the shoulder and thereafter a quarter (90°) turn is given to evenly distribute the cement over the treated surface. The excess cement, which is pushed out of the socket, must be removed at once with a clean cloth. Jointing must be carried out in minimum possible time, time of making complete joint not being more than one minute. Joints should not be disturbed for at least 5 minutes. Half strength is attained in 30 minutes and full in 24 hours. Gluing should be avoided in rainy or foggy weather, as the colour of glue will turn cloudy and milky as a result of water contamination.

Pressure Testing

The method, which is commonly in use, is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. The pressure testing may be followed.

After the specified test time has elapsed, usually one hour, a measured quantity of water is pumped into the line to bring it to the original test pressure, if there has been loss of pressure during the test. The pipe shall be judged to have passed the test satisfactorily if the quantity of water required to restore the test pressure of 30m for hours does not exceed 1.5 litres per 10mm of nominal bore for a length of 1 km.

Laying And Jointing of Pvc Pipes

- Earth Work excavation: Earth Work excavation may be done for laying the PVC Pipes as shown in table 13.2.

TABLE 13.2

S.No.	Outer diameter of Pipe (mm)	Depth of bottom of pipe below G.L. (CM)	Width of Trench at top & bottom (CM)
1	50	105	60
2	63	105	60
3	75	105	60
4	90	105	60
5	110	105	60

- Laying

- PVC Pipes must be laid to the correct depth as indicated above to proper grade and alignment to the extent possible.
- For hard rock, DMR and boulder reaches of pumping main, proper sand cushion of about 10cm at bottom and top of PVC Pipe should be provided to avert damage.
- For providing sand cushion, stack measurement for collection of sand must be recorded in the M-Book.
- If rock out crops are exposed on the surface of proposed alignment, GI Pipes of medium class suitable to join with the PVC Pipes may be laid with proper supports of 0.15 x 0.15 x 0.15m concrete Pillars..
- In the case of hard rock excavated from the trench, stack measurement has to be recorded in MBook.
- Laying of Pipes along the edge of road has to be avoided to avoid damage due to the erosion of soil.
- Laying GI Pipes over the culverts has to be avoided to avert air accumulation and damage caused by vehicles and culprits. Hence may be laid on the sides of culvert with proper protection,.
- The GI Pipes laid for bridge crossing may be supported at 5.00m intervals with R.C.C. columns with necessary fixing arrangements.
- Necessary encasing concrete with anchorage at 5.00 metres intervals have to be done for the pipes laid across the road or sides of culvert below the scour depth to avoid scouring.
- Required air valves may be fixed to the GI Pipes laid on ground or above ground to expel the accumulated air.

- xi) Valves have to be fixed in the pumping main at the following locations as per site conditions (table 13.3).

TABLE 13.3

Air valves	At ridge points (At every 500m distance along the P'Main and also in plains where different in pressure occurs)
Scour valves	At low level points with line sluice valves to be provided beyond scour point
Sluice valves	At branch points
Reflux valves	At appropriate locations to reduce the back pressure if head is high

- xii) Laying of branch pumping main for a longer distance need not be considered if one hand pump of having potable water can meet their requirement.

Jointing Procedure (PVC):

Solvent cement is preferred for jointing the PVC Pipes. The PVC Pipe surfaces have to be cleaned with dry cloth and spigot end is chamfered to 30°. If the jointing surface is contaminated with oil or grease, methylene, cement is applied on the surface evenly with the help of a brush and cleaned by dry cloth evenly to the outer surface of the spigot on one pipe and to the inside of the socket on to the other. After applying solvent, the spigot end of the pipe is inserted into the socket end and the pipe is rotated to 90° for even distribution of solvent cement. Joints should not be disturbed for at least 5 minutes. Jointing should be avoided on rainy or foggy weather.

Requirement of solvent cement.

Outer Diameter of Pipe	No. of coupler joints per Kg of Lubricant
50mm	---
63mm	100
75mm	95
90mm	90
110mm	55

Testing of PVC Pipes

- Pipe line laid has to be tested as per IS: 7364 (Part I) - 1975 for every 500 metres.
- The testing pressure should not be less than one and half times the working pressure of Pipe line under use.
- Water should be filled up in the pipe line either by hand pump or power driven pump to appropriate test pressure.
- Pressure gauge should be correctly positioned and closely observed to ensure that at no time the test pressure is exceeded.
- Air valves should be open at all high points, so that air may be expelled from the pipe line during filling
- After a specified test time has elapsed usually one hour a measured quantity of water is pumped into the line to bring it to the original test pressure, if there has been loss of pressure during the test. The pipe shall be judged to have passed the test satisfactorily if the loss of 30 metres head for 24 hours does not exceed 0.15 litre/mm of nominal size of pipe for a length of 1 km.

Refilling of Pipe line reaches tested.

After testing of pipe line, excavated soil without boulders or large size pebbles should be filled up slowly for 0.60m depth initially layer by layer. The available soil may then be filled up, layer by layer fully.

Other Precautions to be considered

- i) Pipe line should not be laid just above or adjacent to the existing pipe line or cables of EB/Telephone.
- ii) The Electricity /Telephone or other departments may be informed to lay the cables or pipe line on the other side of the road or at sufficient distance from the pipe line laid
- iii) Whether it is Rural or Urban Road, Pipes should be laid far away from the centre of road to avoid damage being caused by the vehicular traffic.
- iv) Necessary protection wall with the available rough stones may be provided at appropriate intervals of Pumping main laid from Low Level points to high level along the sloping ground to avert soil erosion due to rain water. PVC Pipes are not suitable for hot water systems. Further the PVC Pipes should not be laid in the soil containing aromatic compounds.
- v) Alignment of pumping main should not run in private land. If unavoidable the consent letter of the land owner may be obtained in Stamp Papers
- vi) When the Pipe lines have to be laid along/across NH/SH/Railways, prior permission may be obtained.
- vii) The type, size and class of PVC Pipes may be proposed governing the minimum self cleaning velocity of 0.60m/Sec and economical size calculation.

Laying and Jointing of GI Pipes

As illustrated previously, 20mm to 100mm dia GI Pipes of medium class are being used in Rural Water Supply Scheme. In general the GI Pipes are being laid on the ground or above the ground. In hilly areas due to erosion of soil the PVC Pipes are not being used. On the other hand GI Pipes of suitable size are being laid on ground.

Precautions to be taken:

- i) The GI Pipes should not be cranked at turning points as against introducing bends.
- ii) Elbows should not be fixed in lieu of bends.
- iii) Proper supports and anchorage at suitable intervals should be done for the GI Pipes laid on ground to avoid theft and sagging.
- iv) GI Light Class Pipes should not be used.
- v) Proper threading and jointing should be done to avoid leakage.
- vi) GI Pipes should not be laid on slushy soil areas to avoid corrosion. Preferably, it may be laid above ground with necessary supports.
- vii) The type, size and class of pipes may be proposed considering the minimum self cleaning velocity of 0-60m/sec and economical size calculations.

Glass Fibre Reinforced Plastic Pipes (G.R.P.Pipes)

Pipe Installation

GRP pipes being light in weight can be easily loaded or unloaded with stripes or ropes. A pipe can be lifted with only one support point or two support points, placed about 4

meter apart. Excavation of trench and back filling of materials is similar to that in the case of CI and MS pipes.

Pipes are joined by using double bell couplings in following manner.

- Double bell coupling grooves and rubber gasket rings should be thoroughly cleaned to ensure that no dirt or oil is present.
- Lubricate the rubber gasket with the vegetable oil based soap which is supplied along with the pipes and insert it in the grooves.
- With uniform pressure, push each loop of the rubber gasket into the gasket groove. Apply a thin film of lubricant over the gaskets.
- Apply a thin film of lubricant to the pipe from the end of the pipe to the back positioning stripe.
- Lift manually or mechanically the double bell coupling and align with the pipe section.
- Push the coupling onto the pipe by using levers. For large dia pipe, the coupling may be pushed mechanically with even force on the coupling ring.
- Apply a thin film of lubricant over the pipe to be pushed into the coupling just assembled until the stripes on the pipe are aligned between the edge of the coupling.

Thus pipes are coupled together and the rubber gasket acts as a seal making the joint leak-proof. Joint types are normally adhesive bonded, however reinforced overlay and mechanical types such as flanged, threaded, compressed couplings, or commercial/proprietary joints are available.

Depth of Cover

One-meter cover on pipeline is normal and generally sufficient to protect the lines from external damage. When heavy traffic is anticipated, depth of cover has to be arrived at taking into consideration the structural and other aspects. When freezing is anticipated, 1.5m covers is recommended.

Laying, jointing, and testing of pipe lines for distribution mains.

The object of laying distribution system is to convey whole some water to the consumer at adequate residual pressure in sufficient quantity. As such proper design and layout of the system plays a major and vital role. Moreover the system should be economic, easy to design and operate. The distribution system is designed for 30 years. Depending upon the profile of village either a dead end system or a Loop System of distribution net work may be adopted for all practical purposes.

Valves:

In most of the villages dead end system is being followed for distribution mains. Loop system is possible in a big village. Scour valves should be introduced at the end of all dead end lines and at all dip points of distribution main for scouring. In addition, the air valves may also be provided at pipe line ridge points wherever necessary.

13.12. Construction of Slow Sand Filters

The filter structure is constructed in RCC. Some of the important considerations that need attention during construction are:

- i. the type of soil and its bearing capacity,
- ii. the ground water table and its fluctuation,
- iii. the availability and cost of construction material and labour.

Water tight construction of filter bed should be guaranteed, especially when ground water table is high. This will prevent loss of water through leakage and contamination of filtered water. The top of the filter box should be at least 0.5 m above the ground level in order to keep away flood water, dust, animals and children. The pipe drainage system for collection of filtered water should be carefully laid as it cannot be inspected, cleaned or repaired without complete removal of the filter sand and gravel.

13.13. Valve Pits

Necessary valve pits have to be constructed for sluice valves, scour valves and air valves housing. The standard design for valve pits is shown in table 13.4.

Table 13.4

Main in (Inner dia)	Depth to bottom of pipe line mm	Depth to top of concrete in mm	Thick ness of foun dation con crete in mm	Length of foundation concrete in mm for valve	Width of pit inside mm	Length of pit inside mm	Wall thick Ness in mm	Width of foundation concrete in mm	Length of foundation concrete in mm	Thickness of RCC/ precast slab in mm
80	1050	1200	230	230	750	900	230	1500	1650	100
100	1050	1200	230	255	750	800	230	1500	1650	100

13.14. Public Stand Posts

In order to affect supply to the consumers, the Public stand post is being located at appropriate location for every 150 persons. It consists of RCC stand post of 0.15 x 0.15m x 1.5m height. Necessary platform is provided in front of stand post for fetching water. Saddle piece, 20mm dia GI Pipes and ferrule with taps are provided from the main line to Public Fountain. In this regard, 5 type designs are available in the Rural Water Supply Manual Based on the availability of space suitable type design may be adopted. Schematic diagrams for public stand post are shown in Fig.9.3 and 9.4.

Precautions to be taken

- For pipe connection, 20mm dia GI Pipes of medium class and bend may be provided.
- The PCC laid for platform for 40 cm depth below the ground level is insufficient and erodes day by day and finally it is being damaged. Hence earth work excavation for minimum 0.60m may be taken. Sand filling for 0.10m and PCC 1:4:8 for 0.10m may be provided. For balance height of 0.40m, PCC 1:2:4 with 20mm HBG jelly may be provided and finished. For sides of Platform, PCC 1:2:4 of 0.10m x 0.10m may be provided around the platform with necessary drain up to soak pit

Guide Lines to be Followed

- Location of public fountains should be decided in consultation with user community.
- The platform design need not be uniform. It can vary to suit the site conditions
- Proper steps should be given to prevent stagnation inside the platform and also in the drains.
- The Waste water from the tap should not be allowed to run on the streets and to be let into the sock pit.

13.15. House Service Connection

In order to obtain water charges for operation and maintenance of scheme it is proposed to provide House Service Connection to fetch water in the house premises itself at their request.

Materials Required

- i) 63mm x 15mm dia PVC saddle piece is fixed in the distribution Pipe. Necessary boring of 15mm dia will be made at top of pipe.
- ii) 15mm dia GI medium class pipes, couplings, nipples, elbows and 15mm dia tap are to be fixed in the connection.
- iii) Ferrule to conform to IS 2692-1978 and to be fixed in the distribution line.
- iv) Suitable Water Meter has to be fixed in the pipe line at safe place to assess the quantity of water being drawn by the consumer

Purpose of Ferrule

- i) It is an integral part of a House Service connection.
- ii) It is used to control the flow of water to an individual house.
- iii) The ferrule is used for cutting of the supply to defaulting consumers.

Purpose of Water Meter

- iv) It is an integral part of a house service connection.
- v) The water meter fixed should conform to IS..
- vi) It is used to measure the quantity of water consumed by the House hold.

13.16. Sanitation (TPPFL) Materials:

The squatting pan can be of ceramic, glass fibre reinforced plastic (GRP), high density polyethylene (HDPE) or polyvinyl chloride (PVC) polypropylene (PP), cement mosaic or even concrete superstructure. However, the ceramic pans are favoured in this project due to their better non-sticking and non-staining properties.

A minimum latrine size of 750 x 900 mm is recommended. The superstructure of latrine cubical could be brick or stone in mud or in cement mortar. The superstructure could be of very low cost if constructed with bamboo matting with mud plaster outside and inside with thatched or tiled roof.

Observations to be made during construction

During construction, one should check whether the following conditions have been met:

- The depth of the pit below the invert level of connecting pipes or drain shall be as given in relevant drawings.
- If the maximum ground water level throughout the year remains 2 m or more below the pit bottom, and if the soil at site is fine (effective size 0.2mm or less), the pits have been located maintaining a minimum distance of 3 m from the drinking water sources. If the water table is higher, a minimum 10 m distance be kept to minimize the chances of pollution.
- If the soil at the site is coarse (effective size more than 0.2 mm), a 500 mm thick envelope of fine said of (0.2 mm effective size) has been provided all around the pit, its bottom sealed, it is located at a minimum distance of 3 m if ground water table in any part of the year is 2 m or more below the pit bottom. If the water table is higher,

a minimum distance of 10 m has been kept to prevent pollution of drinking water sources.

- The pit size conforms to the geological and hydro geological conditions and the likely number of users, and adequate leaching area has been provided, if necessary, by back filling for proper infiltration of incoming liquid into the pits. In cases where the foundation is very close to the pits, holes have not been provided in the portion of lining facing the foundation, and the leaching area has been increased suitably.
- The minimum distance between the two pits shall be equal to the effective depth (depth of the pit below the invert of incoming pipe or drain) of the pits.
- The minimum distance between the two pits shall be equal to the effective depth (depth of the pit below the invert of incoming pipe or drain) of the pits.
- The pits shall not be located in a depression where water may stagnate over the pits or in a drainage line which allows the flow of rain water over the pits.
- The bottom of the leach pit has been left in a natural condition except where it is necessary to seal it to prevent pollution.
- The RCC cover is as per designs.
- The top of the pit cover is about 50 mm above the natural ground level and the earth fill is well compacted all around the cover sloping to avoid a step being formed.
- The drains is “U” shaped, cross-sectionals and its inner surface is smooth.
- Drains with benching have been properly provided in the junction chamber to divert the flow to one of the two pits.
- A minimum gradient of 1:15 has been provided in the connecting drains or pipes. The mouth of the drains or pipes is projecting nearly 75 mm past the pit lining in the pits.
- The flow has been restricted to one pit by blocking the mouth of one of the drains or pipes.
- The materials used are of the quality specified in the design, or relevant standard specifications and the workmanship is good.
- The specifications laid down have been followed and the work has been finished nearly.
- The floor surface is smooth and sloping slightly towards the pan.
- The foot-rests have been fixed at the proper place and at an angle, as in the drawing.
- 50 mm wide holes have been provided in the pit lining in alternate layers up to the invert of the pipe or drain, and the lining above is in solid brick work (no holes). If the soil is sandy, or if a sand envelope has been provided, or there are chances of damage by field rats, the width of the holes has been reduced to 12 to 15 mm. If the foundation of the building is close to the pits, holes have not been provided in the portion of lining facing the foundation. In element concrete ring lining, rings below the invert of pipes or drains should have 50 mm circular holes staggered about 200 mm apart.
- The covers over the pits, drains, and junction chamber have been placed properly.
- The pan and trap used are of a design specified for pour flush and these have been fixed properly so as to provide a 20 mm water seal, and that the joint is water tight and the top of the pan is flush with the latrine floor.
- No vent pipe has been provided.

-
- A well-ventilated superstructure has been provided to enable use of the latrine.
 - All surplus materials have been removed and the site cleared and dressed.
 - The users have been educated on these and maintenance of PF latrines.

13.17. Septic Tanks

Construction Care: Only that material shall go into the construction of a septic tank which offers guaranteed strength and water tightness. The masonry is done in rich cement mortar and plastered inside. With 1:3 cement-sand mixture. In bed C.C. 1:2:4 should be used. In case of small tanks one manhole cover above the inlet serves the purpose but in case of large tanks, two manhole covers of water tight and double seal design depending upon the expected load should be used. Staggered M.S. steps are provided to facilitate access to the manhole.

Ventilating pipes are provided in every septic tank. On the top of ventilating pipe is provided a suitable cover of mosquito proof wire mesh. The height of ventilating pipe should extend to at least 2 m above the top of the highest building within a radius of 20 m.

CHAPTER – 14

14. COMPLETION PLAN AND REPORTS

When a project is completed, commissioned and handed over, the history of the project is to be maintained. The advantages of the keeping records is

- It will be helpful while carrying out the O&M.
- It will act as a guide for future projects
- It will examine the mistakes committed, and study to avoid mistakes in future projects

14.1. Completion Drawings

On execution of scheme it is required to prepare drawings of all components as per the work done called completion drawings. These are modified from working drawings. The completion drawings should indicate all changes made during execution.

The list of drawings required is

- Site plan or Location plans.
- Village map
- Plan showing bore well/open well with cross sections.
- Plan showing pumping main, showing alignment, distance and position of valves. Size of pipes and type of pipes should be marked
- Plan showing Intake well with cross sections.
- Plan showing Service Reservoirs with all designs.
- Plan showing details of Treatment units
- Plan showing distribution System, showing alignment, distance, position of valves and position of Public stand posts. Size of pipes and type of pipes should be marked
- For all civil works the material of construction, classification, and foundation details should be shown.
- For all plans dimensions should be marked.
- Permanent bench marks should be marked
- Levels at which components taken up should be marked.

14.2. Completion Reports

The completion Report shall contain all the text information of the project that may be required in future reference. This will be useful for carrying out O& M activities and for upgrading scheme.

The completion Report shall have the following information.

General information

- Name of the work
- Estimate cost
- Administrative Sanction No, Date and authority.
- Technical Sanction No, Date and authority.

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- Work order No, Date and authority
 - Name of the agency executed the work
 - Name of the Implementing office
 - Date of Commencement of work
 - Time scheduled for completion of work
 - Date of completion of work
 - Date of hand over to GPWSC.
 - Final payment made.

General Abstract

The general abstract of the scheme is to be prepared along with comparative/completion Statement showing the deviations. The completion proforma should also be prepared for each of the sub work, clearly indicating all the details of work.

Performance of key agencies, activities should be informed in reports

- Performance of contractors
- Performance of key agencies
- Performance of GPWSC/Community.
- Difficulties faced during construction.
- Coordination required with other organizations.

CHAPTER – 15

15. OPERATION AND MAINTENANCE

15.1. Introduction

Any water supply system, how well engineered it may be, can give satisfactory service to the community unless it is properly and effectively maintained. Maintenance unit is the nerve centre of water works organization. The success or failure of this unit is judged from the increase or decrease in number of complaints received. The operation refers to the art of handling the system in such a manner that designed quantity and quality of water can be produced. The scope of maintenance of water system will vary depending upon the particular situation.

The maintenance of water works may refer to well keeping the civil, mechanical and electrical components of a plant through normal repairs, so that they are able to function at designed capacity for their design period. It may further refer to such routine repairs as they are necessary to prevent the components from malfunctioning.

The operation refers to the art of handling the plant and equipment optimally so that the designed quantity and quality of water can be produced.

The operation of water works refers to hourly and daily operation of certain component parts of the water works such as plants, equipments, valves, machinery etc., which are required to be attended to by an operator or his assistant. It is an important routine work. Operators have to be trained properly before they are entrusted with the task of operation of specific plant, equipment, valves, machinery etc.,

In the operation and maintenance of water works, there are certain common features to be considered by the authority controlling the water works and are briefly Stated below:

15.2. Availability of Detailed Plans, Drawings and O & M Manuals

When a water work is taken over for operation and maintenance, it must be ensured that atleast five to six sets of the detailed drawings, maps of each of the component of the water works along with the relevant O & M Manual are available with the operating authority. One of the sets may be preserved as a master set in apex office for reference. The other sets may be distributed to sub-offices in charge of relevant operation activity. All these sets must be corrected and updated whenever any additions / alterations / deletions are done to any of the structures and equipment.

15.3. Schedule of Daily Operations

For each of the activity where operators are employed, a detailed scheme and schedule of unit operations should be worked out and a copy of the same should be available with each operator. This schedule of unit operators may have to be altered to suit changes in raw-water quality, hours of availability of power, break-downs and up-set conditions etc.,

15.4. Machinery and Equipment

A regular schedule of inspection of machinery, equipment their lubrication and servicing programme must be prepared and circulated. Appropriate supervisory control should be exercised to see that these inspections, lubrications and servicing are being regularly carried out. Proper maintenance of pumping machinery needs a trained and skilled staff and should be well conversant

with the equipment. In several cases, a simple trouble which can be set right with a spanner by a skilled hand is converted into a major overhaul by unskilled or semiskilled hand.

It is of utmost importance to follow the manufacturer's recommendations for operation and maintenance procedures. On the basis of the recommendations of the manufacturer of the equipment, a schedule of preventive maintenance should be drawn in a simple language to be easily understood by the maintenance staff. It should be ensured that the schedule of maintenance is strictly followed. Only the recommended lubricants shall be used. Sufficient space should be available for carrying out repairs and for keeping oil, grease, spare parts and tools etc.,

The spare parts required for routine maintenance shall be procured well in advance to avoid unnecessary delay in carrying out repairs.

It is necessary to have a good workshop for this purpose, particularly in case of large installations. The repair of heavy equipment, depending upon the scope of repair involved, may require a truck, electric generator, flood lights with extension cards, a small crane for handling the materials safely during repairs. The workshop should have the facility of welding set, grinder, drilling machine, small lathe and any other equipment depending upon the scope of repair involved.

The operator should be able to clean the plugs of petrol engine, to change and adjust belt drives, to clean fuel filter, air filter and cooling system. He must not handle the injector system in the diesel engine himself. On reciprocating pumps he should be able to change cup leather and carry out similar nature of minor servicing. The most important point for the operator to understand is to know when to call for skilled assistance, for instance where there is trouble because of worn out bearings requiring proper alignment etc., The operator should however be able to maintain log book properly and regularly indicating the fuel consumption, hours worked and quantity of water pumped etc., The log book of the equipment should also indicate the record of break downs and repairs, data wise and cost of repairs and consumption of fuel etc., This record would provide a fairly good idea and timely indication about the particular equipment being worn out, requiring major over-haul or replacement. A typical format, for a log book of a pumping plant to serve as a guide is given below.

Daily log sheet of pumping station for the month of										
Date	Pump No.			Pumping Time	Volts	Amp.	Quantity of water Pumped Kld @ lph; Capacity of pump)	Electric consumption Meter No.....		
		Start	Stop	Hrs : mts				Reading of Meter		
								Initial	Final	Consumption Kwh
1	2	3		4	5	6	7	8		

GUAGE READING		REMARKS
VACUUM	DELIVERY	This Column should be used to indicate: (1) Break down and repairs, date wise: (2) Cost of repairs. (3) Fuel consumption in case of diesel/petrol engine, (4) Any other important event in the performance of machinery like rise in temperature of bearing, undue noise or vibration, leakage in stuffing box.
kg/cm ²	kg/cm2	
9	10	
		11

The first page of the log book should contain detailed particulars, make and size of various components of the machinery installed along with date of installation with test results. These particulars or to be carried over to the subsequent log books so as to make the information always readily available.

It is extremely essential to provide a communication (telephone, wireless, etc) and transport facilities at the plants. In case of emergency situations requiring some unexpected spare part or material, adequate communication and transport facility can only help to arrange the required material promptly.

The engineer-in-charge of maintenance shall keep readily with him the names and addresses of firms dealing in spare parts and other essential requirements. Because of the constant changing maintenance techniques, efficiency of maintenance staff shall be enhanced by proper trainings.

15.5. Operation and Maintenance of Hand pump

Operation of the hand pump is simple, but, for trouble free service the following cares shall be taken while using.

- Use the pump gently
- While extracting water give long and slow strokes to the handle
- Keep the surrounding of the hand pump clean
- Pump should be operated by one person only at a time.
- Provide good drainage to wastewater from the vicinity of the pump
- Do not allow children to play with the pump
- Prevent entry of cattle near hand pump
- Do not allow any one to seat on the handle of the pump
- Do not wash clothes, or utensils on the pump platform

Maintenance once in a month

- Tighten the handle axle nut & lock nut
- Look for loose or missing flange nut & bolts
- Open the front cover, clean the inside pump
- Check the chain anchor, bolt for proper fitment. Tighten it if necessary
- Clean the chain assembly. Apply graphite grease
- Look for rusty patches, if seen clean and apply paint.
- Find out whether the hand pump base is loose in the base. If it is loose arrange for fresh foundation

Maintenance once in a year

1. Examine the pump carefully and check whether
 - Discharge is satisfactory
 - Handle has any shake
 - Guide Bushes are not excessively worn out
 - All the nut and bolt washers are in position
 - Chain is not worn out
 - Roller chain guide is not excessively worn out

Take appropriate corrective action to rectify the above defects

2. Pull out the pump and check the following
 - If bearings, spacers are damaged, replace them
 - If roller chain guide is badly damaged or worn out, replace handle assembly
 - Fill the grease between bearings
 - If pipes are damaged, replace them
 - Open out cylinder assembly & replace cup washer, sealing ring and also any other parts found defective
 - Check the condition of water tank, riser pipe holder, if threads are worn out replace the water chamber.
 - Check all sub-assemblies for cracks in welding and other visual defects. If defective, replace sub-assemblies.
 - Reinstall the pump as per the instruction

3. Paint the pump inside and outside

Trouble Shooting

S.No	Problem	Probable Causes		Remedies
1.	Pump Handle is working easily but no flow of water	A	rising main is damaged or disconnected	Replace the damaged pipe or connect the affected raising main
		B	Water level gone down below the Cylinder Assembly	Add more pipes & rods
		C	Cylinder, leather bucket is worn out	Overhaul the cylinder & replace leather bucket
		D	Connecting rod joint is disconnected	Pull out the pump and join the connecting rod wherever it is necessary
		E	Valves seat is worn out	Replace the Valve seat
		F	Pump cylinder is cracked	Replace the cylinder Assembly
2	Delayed flow or less flow	A	Leakage in cylinder bottom check valve or upper valve	Overhaul cylinder. Replace rubber seal
		B	Leakage in pipe assembly	Replace rising main
3	Folding of chain during turn stroke	A	Improper erection	Adjust the length of last connecting rod suitably
		B	Leather cup washer getting jammed inside the cylinder	Over haul the cylinder & replace the leather bucket
4	Noise during the operation	A	Stand Assembly range not leveled property	Level the flange
		B	Bend in connecting rod	Change the defective rod
		C	Hexagonal coupling welded off set	Change the defective rod
5	Shaky Handle	A	Loose handle axle nut	Tighten the handle axle nut
		B	Worn out ball bearing	Replace the ball bearing
		C	Spacer damaged	Replace the spacer

Tools requirement for installation and maintenance

A) Standard Tools

S.No.	Standard Tools	Quantity
1	Button Die to suit M 12 x 1.75 threads	1 No.
2	Die set for 32/20 mm N.B. pipe	1 set
3	600 mm pipe wrench	2 Nos.
4	450 mm pipe wrench	1 No.
5	M 17 x M 19 double ended spanners (10 mm x 12 mm)	2 Nos.
6	Screw driver 300 mm long	1 No.
7	1 Kg ball-pin hammer with handle	1 No.
8	Hacksaw frame with spare blade of 30 Cms	1 No.
9	Pressure type oil can (1/2 pint with oil)	1 No.
10	Wire brush	1 No.
11	250 mm round file with handle	1 No.
12	250 mm flat file with handle	1 No.
13	Graphite grease and Lithon-3 grease	1 Kg – each
14	0-9 number punch (6 mm)	1 set
15	Nylon rope (3 mm thick)	75 m
16	Tripod stand and 2 ton capacity chain pulley block with 5 m long chain	1 No.
17	Adjustable spanner	1 No.

B) Masonry Tools

S.No	Tools	Quantity
1	Scoop	3 Nos.
2	Pan	4 Nos.
3	Spade	3 Nos.
4	Crow bar	2 Nos.
5	Spirit level(250mm)	1 No.
6	Leveling plank wooden (small and large)	2 Nos.
7	20 lit Mug	1 No.
8	2 lit Mug	1 No.
9	Measuring tape (3 M)	1 No.
10	Quick setting compound	1 No.
11	Tube well cover plate	1 No.
12	Pedestal cover plate	1 No.
13	Plate for shuttering unit	1 No.

15.6. Submersible Pumps

The Submersible pump unit comprises of single or multistage centrifugal pump and water filled squirrel cage motors. Both pump and motor have water lubricating plane bearings. This can be installed vertically or horizontally in clean water. The motor is to be filled with water before installation. This pump will give trouble free satisfactory service if it is properly installed and maintained. Maximum installation depth is 160 meters. Pumps should never be allowed to run dry.

15.7. Maintenance of Submersible pumps

If pumps are operated properly much maintenance is not required as all bearings are water lubricated

Repair of the pump and Electric Motor

This requires good workshop facility and skilled workmanship and special tools. It is advisable to send this pump to manufacturer's authorized service center for repairs.

Trouble Shooting

S No	Problem	Probable Causes	Remedies
1.	Pump set does not deliver any water	Water level has fallen below the level of the pump	<ul style="list-style-type: none">• Stop the unit until water level rises naturally• Ensure that the flow is not obstructed• If possible lower the unit further
		Wrongly connected non-return Valve on the delivery line	<ul style="list-style-type: none">• Check the flow direction arrow on the non return Valve and connect it properly.
		Motor is not starting	<ul style="list-style-type: none">• Check for correctness of incoming power supply• Check for continuity in cable• Check for back-up protection
2	Pump does not deliver sufficient quantity of water	Motor running at lower than rated voltage	<ul style="list-style-type: none">• Ensure that the supply voltage is proper.• Ascertain if there is voltage drop in the cable if so replace it with the cable of higher size.
		Strainer /Impeller / Stage Casing may be clogged	<ul style="list-style-type: none">• Check the piping joints for leakage.• Clean the strainer and the flow passage of impeller and stage casing. If required replace them.
		Increase in the internal clearances due to the wearing at impeller eye, periphery / Impeller / worn out guide vanes and flow passages	<ul style="list-style-type: none">• Replace the worn out component

S No	Problem	Probable Causes	Remedies
3	Pump set consumes excessive power	Motor may be running at a speed higher than the rated OR Low voltage across the motor terminus OR Pump set run outside the recommended range	<ul style="list-style-type: none"> Check the supply voltage & frequency if necessary replace the cable with higher size. Ensure that pump set is operating nearer the best efficiency point Consult the authorized dealer/service center
4	Excessive noise and vibration	Excessive air intrusions in the water pumped . OR Chances of water hammering in the piping system	<ul style="list-style-type: none"> Lower the unit further in the water Install a suitable NRV to minimize the effect of water hammering in the piping
		Improper piping system	<ul style="list-style-type: none"> Ensure proper support to piping and bend.
		Worn out and defective bearing in motor	<ul style="list-style-type: none"> Replace the bearings
5	Motor Burns Out	Defective motor protection device	<ul style="list-style-type: none"> Consult the control panel expert
		Improper cooling of the motor	<ul style="list-style-type: none"> Motor may be dipped in the sand/mud and grit obstructing heat transfer
		Misalignment in the pump set coupling	<ul style="list-style-type: none"> Replace properly
		Faulty back-up protection system	<ul style="list-style-type: none"> Refer to pump manufacturer / Supplier
		Fault back-up protection system	<ul style="list-style-type: none"> Refer to pump manufacturer/supplier
		Motor started without filling the water	<ul style="list-style-type: none"> Fill the motor with clean and fresh water before startup
		Continuous operation of water at low voltage	<ul style="list-style-type: none"> Voltage in electricity supply to be corrected. Operate pump only , if the electricity supply is proper.

15.8. Centrifugal Pumps

Centrifugal pumps are supplied with electric motor fitted on the common base frame. And the Guidelines for proper use of Pumps

- There should be drop wise leakage from the pump gland packing, when the Pump is running. This ensures heat dissipation
- Surrounding area should be kept clean
- Do not overload the machine
- Do not run without greasing and oiling
- Do not run pump with suction valve closed
- Do not run pump if suction line and strainer is choked
- Do not run pump for other than specified liquid
- Do not run pump when water is below suction inlet
- Do not run pump if casing/motor is getting heated
- Do not run pump if alignment is not proper
- Do not put extra load on pipe valve and pumps
- Do not run pump if gland leakage is heavy
- If equipment is kept for idle for long time, drain the water from the pump and disconnect the pump motor. Open end to be greased the covered and packed in wooden box and date it.

Safety Practices in O & M of Pump

- While carrying out inspection/repair on pumps, main electric supply should be switched off and fuse removed. This will prevent unintended/accidental start of pump during inspection
- Equipment should be covered with proper shed
- Ensure that coupling guard is in place before starting the pump
- Electric motor and cooling fan should also have safety guard
- All valves, main switch, emergency stop switch should be located at suitable height to easy and safe access
- Electric cable should be properly clamped at loose end
- Lifting of pump and electric motor should be done by using chain pulley block

Maintenance

A) Day to day checking schedule

- Clean the pump from the outside thoroughly.
- Rotate the Pump & Motor by hand 2-3 turns. it should move freely.
- Check the oil level of the pump bearing housing. (if the pump is oil lubricated)
- Pump bearing to be greased by turning the grease cup by half turn. Grease cup is mounted on the pump bearing housing. (For grease lubricated pump).

B) Weekly Schedule

- Clean the pump from outside. Check for any leakage
- Check the foundation bolts, if loose, tighten it.
- Check the coupling pin and bush condition, if damaged replace it.

- Check pump's suction and delivery line, flanges, nut & bolts, if loose tighten it.
- 1. Check the gland leakages, if leakage is more, tighten the gland follower nut slightly.
- Check the pump suction delivery valve gland leakage, if it is more, tighten the gland follower nut.
- Check the valve operating condition by opening and closing.
- Lubricate the pump bearings by turning the grease cup 4 times.
- If it is oil lubricated, top-up the oil level

C) Yearly Schedule

- Decouple the pump
- Check the coupling fitment on the pump shaft if loose, try changing keys and grub bolt still if it is loose replace the coupling halves having correct size bore and key way.
- Drain the lubricating oil from the bearing housing with fresh oil and fill fresh oil of proper grade as recommended by pump manufacturer. (For oil lubricated pumps)
- Remove the bearing covers, clean the bearing grease, apply the fresh grease, fit the cover back (this is applicable in case of grease lubricated pumps).
- a) Check the pump shaft by hand, by turning, lifting up and down; if there is a play, the pump needs to be overhauled.
- Check the pump axial play by moving horizontally, if the play is more, pump need to be overhauled.
- Pump foundation bolts to be checked, if loose, tighten.
- Check the grouting of the frame, if loosened, regrout it with cement concrete
- Pump Gland Packing to be removed and checked, if it is found damaged, pump needs to be overhauled
- Replace joint packing between pump suction & delivery nozzles and lines
- Check pump electric load, if it is less or more than specified, pump needs to be overhauled.
- By turning the pump shaft, bearing condition noise to be checked, if it is abnormal, pump needs overhauling.
- Check for pump and motor alignment, if it is disturbed, realign it.
- Calibrate pump delivery line pressure gauge
- Get pump suction valve, delivery valve, NR valve, and foot valve overhauled & hydraulically tested
- Provide fresh gland packing to pumps and valves
- Check line and valves supports. If it is not working overhaul or replace
- Paint pump, lines, and valves

15.9. Maintenance of Electric Motor

There are several factors detrimental to the life of an electric motor.

Moisture of Electric Motors: Presence of moisture is not good for motor insulation. Motors should always be located in dry place. For moist locations drop proof, splash proof or totally enclosed motors should be used else the winding will be damaged.

When motors are stored in unsuitable conditions where they can absorb moisture, it is essential to dry them thoroughly before commissioning. If the insulation resistance falls 1.0 mega ohm, the

motor winding should be dried by any of the methods such as hot air blast, by means of hot stove or oven. Winding temperature should be maintained at about 90°C.

Low Voltage Supply: Voltage lower than that specified on the name plate of the motor is detrimental to the motor in respect of performance and life expectancy. Low voltage will cause the winding to heat up even at low loads and the current drawn by the motor will be higher.

Dust: Dust has been cause for many motor failures. Its action is slow but sure. It is essential that preventive measures are taken to off set the dust accumulation and to blow it out occasionally from winding by a portable electric blower or with such other equipment.

Oil: Oil is very harmful to the winding insulation because once the winding is soaked with oil, it is in danger of immediate burn out or break down. It is, therefore, essential to ensure that oil does not come in contact with the winding. To remove it, use non-inflammable solvent like carbon tetrachloride, but with caution because the latter has softening effect on the winding insulation.

Bearings: Bearings run well if properly lubricated. Insufficient or excessive supply of lubricants should not be resorted to, both being harmful to bearing life. Again correct grade and type of lubricant should be used.

Misalignment: Motor damages such as shaft being springing or broken, bearing getting worn-out or over load failure are often caused by misalignment. This defect can be in the motor or in pump and it should be carefully located and removed.

Vibrations: Misalignment is one of the important causes of vibrations. In order to locate the source of vibration disconnect the vibrating motor. If the motor operates far more smoothly when disconnected and if its alignment is found to be proper, the pump should be examined for the source of vibrations.

Overload: To protect the motor from danger due to over load, various devices are incorporated in the starting mechanism of electric motors.

(a)Electric motors are required to be protected against the hazards of current fluctuation and overloading etc during the operation by the use of certain devices which break the electric circuit when fluctuation is more than the predetermined value. The simplest device is the fuse to prevent excessive current to the motor, but the surges of power are not destroyed by the fuses or sometimes only one fuse blows off.

(b)Relays and circuit Breakers: The relays are used as automatic devices for breaking the circuit under fixed conditions. These devices are widely applicable and accurate. These are reliable in action and can be adjusted with precision to control the time of opening or closing of a switch. The circuit breakers are higher in initial cost but are preferable on circuits subject to frequent over loads.

Standard relay can be adjusted for any current range and provides an instantaneous trip. Immediate repeat operation is possible. This works as single phase preventer also.

Whenever an overload device operates, it has to be rest before motor can restart. The resetting may be automatic or manual. Whenever an over load device operates, the cause should be taken as warning. It may be due to low voltage, overload, Jammed or hard bearing, Single phasing etc.

15.10. Burn-out of New Motors

At times, brand new motors fail on the first switching or shortly after commissioning. Main reasons of this failure are:

- i) Occurrence of single phasing in the supply system.

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- ii) Accumulation of water inside the motor.

It has been found in experience that under certain circumstances, totally enclosed motors are highly susceptible to damage by the atmospheric moisture. Whenever totally enclosed motors have been standing idle for more than two or three weeks in an unheated building it will be a good practice to examine before putting them in operation. If the slightest trace of water is found inside the enclosure or if there be an indication like rust on the steel shaft or iron parts inside the machine, the safest rule would be to presume that the winding has absorbed moisture and to dry them before setting it to works.

15.11. Faults in Motors and their diagnosis

S.No.	Problems	Probable causes	Remedies
1	No rotation	Supply failure (either complete or single phasing or reversed phase)	Disconnect motor immediately or burn out may occur. Check all connections against diagram.
		Control gear open circuited	See that there is no break in cables and that terminals are clean and tight. Examine each section of all control gears for bad contact or open circuit
2.	Motor starts but will not take load	Wrong setting of overload trips	Set over-load trips to approximately 150% of full load current
3.	Sparking of brushes	Brush pressure too light	Adjust to correct pressure. Also rub brushes and smooth out slipring surface roughened by sparking.
4.	Steady Electrical Hum	Running single phase	Check that all supply lines are live with balance voltage.
		Excessive load	Compare line current with that given on the motor rating plate. Reduce load or change with higher rating motor.

S.No.	Problems	Probable causes	Remedies
5.	Mechanical noise	Foreign matter in air gap	Check air gap, dismantle rotor and clean rotor and starter
		Bearing damaged	Fit new bearing, check coupling gap and re-align
6	Vibration	Uneven foundation	Check level and re-align
		Foreign matter in air gap	Uncouple from driven machine, remove coupling, run motor to determine whether unbalance is in the driven machine, pulley or motor Re-balance.
7	Over-heating of winding	Excessive load	Reduce the load or change to larger motor
		Foreign matter in air gap	Check air gap. Clean rotor and starter
8	Over-heating of brushes	Too much grease	Remove surplus grease
		Too little grease	Wash bearing and replenish with grease.
		Bearing overload	Due to misalignment. Re-align and reduce the load and thrust.
9.	Over-heating of bearings	Excessive load	Compare line current with that given on the motor rating plate. Reduce load or change to larger motor.
		Incorrect grade of brush	Use-correct grade of brush as per manufacturer's recommendation.
		Brushes not bedding or sticking in holders. Light brush pressure, hence sparking.	Carefully re-bed or clean brushes and adjust to correct pressure.
10	High starting current in slipring motor	Due to interchange of cable leads of different phases in the motor circuit.	Identify cable leads of each phase at: a) Leads through shaft terminating a slip-ring collector b) Brush leads terminating at rotor terminal box. Re-adjust correctly.

A) Daily Schedule

- Observe input supply. It should be 440 to 450 voltage. In case it is very low/very high do not run the motor
- Check the working of pilot lamp/indicator lamp on switch board
- Working of ampere meter
- Check electric motor and fan by turning with hand 2-3 rotations. It should rotate freely. Fan should also rotate and should not fowl with casing.
- Check that the coupling guard, motor fan end cover are in place
- Electric motor foundation bolts to be checked and tightened

B) Monthly Schedule

- Decouple the electric motor, run electric motor alone, check no load current, it should be within specified limit. If in excess refer the matter to motor supplier
- Check for bearing running conditions, grease the bearings, if dry
- Check the electric motor foundation boards and tighten if loose
- Check coupling pin bush

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- Electric motor terminal box if open to be fitted properly, if missing provide new.

C) Yearly Schedule

Note: This job is to be done only by qualified wireman under the supervision of a licensed supervisor.

- Check the main switch, pilot lamp, earthing connections, ampere meter and volt meter conditions.
- Check the cable supply from main switch to electric motor.
- Take the over hauling of electric motor
- Dismantle the electric motor remove the rotor
- Check the rotor at both ends and at bearing location
- Test the rotor winding. If it is damaged, get it repaired.
- Check rotor for dynamic balance. Check rotor shaft for trueness.
- Check shaft key way size
- Get the motor and motor cover painted
- After all test and repairs, assemble the motor with new bearings.

Major Repairing of the Pump :

Major repairs be carried out at manufactures workshop or at site by a factory trained technician

For maintenance and repairs at site following drawing are required

- RCC foundation
- Pump suction delivery line drawings
- Pump and motor frames
- Electric panel board
- Layout

Consumable items available in Tools Box

- Grease
- Cotton waste
- Fire play joint sheet
- Rubber joint sheet
- Teflon sheet 3 mm
- Teflon tape
- M – seal
- MS plug
- Select compound bottle
- Gland packing (champion types 2222, 6 mm and 8 mm)

Tools

- Box spanner set mm size
- Box spanner set inches size fix spanner set inches and mm sizes
- Ring spanner set inches and mm sizes
- Hammer
- Allen key set
- Hack frame with blade

- Half round flat 12 inch 6 inch smooth and rough file
- Chisel
- Screw driver 8 inch 12 inch 18 inch
- Needle pliar
- Hand pliar
- Table vice
- Screw spanner
- Pipe range 12 inch, 18 inch
- Measuring tape 3m
- Filter gauge
- Outside and inside caliper
- Divider
- Hole punch
- Test lamp

Routine maintenance work that can be attended at site by operators are

- Lubrication
- Tightening and Changing Gland Packing
- Cleaning Suction Pipeline, foot valve and Strainer etc
- Maintenance work in suction and delivery pipeline

Lubrication shall be carried out as per the instruction of manufacturer as per recommended schedule and using recommended grade of lubricants

15.12. Trouble shooting of Pumps

S.No	Problem	Probable Reasons	Remedies
1	Pumps does not deliver water	Suction pipe, foot valve choked (applicable where foot valve is provided)	Disconnect suction pipe from pump. Remove foot valve from suction pipe. Clean it. Check foot valve seat for leakage or damage. If foot valve seat is damage replaced the foot valve. If foot valve seat is okay, clean the pipe from inside and fit the foot valve back to pipe. Connect the suction pipe to pump. Start the pump for trial.
		Valve in the suction line not open	Pump suction line is provided with a valve. This valve should be fully open for satisfactory operation of pump. Make sure that the valve is fully open. This can be checked by spindle raise length and by feeling while opening and closing.
		Joints in the suction line not leak-proof	Check the suction pipe and flanges for leakage and if require replace them
		Strainer in the suction line clogged	If a strainer is provided in the suction line, remove it, and check it, if clogged clean and refit.

		Impeller clogged	Disconnect the pump suction line, remove the pump volute. Check the impeller. If it is clogged with mud, sand, leaf grass or any other foreign material, clean it, fit the volute and suction line back with new packaging, and take trial. In order to avoid foreign material entering into impeller provide a “Y” type strainer in the suction line if not already provided.
		Number of revolutions too low	Decouple the motor, check the electric motor RPM. If it is low, check the electric supply or replace the electric motor with correct RPM. RPM can be measured by using a tachometer.
		Incorrect direction of rotation (electric motor incorrectly connected,, leads of phases on the terminal block interchanged)	Electrical motor direction of running should be as per the pump direction. If it is in opposite direction then it will damage the pump. Decouple electrical motor and run for the trial direction should be as per the arrow marked on the pump. If otherwise correct the direction by inter changing the phase connections in the motor terminal box. (this work should be carried out by trained electrician only)

2	Pump Delivery at Reduced Capacity	Suction pipe, foot valve partially choked	Disconnect suction pipe from pump. Remove foot valve from suction pipe. Clean it. Check foot valve seat for leakage or damage. If foot valve seat is damaged replaced the foot valve. If foot valve seat is okay, clean the pipe from inside and fit the foot valve back to pipe. Connect the suction pipe to pump. Start the pump for trial.
		Suction pipe not sufficiently submerged	Pump suction pipe must be submerged in water. Water level must be above foot valve. Stop the pump till the water level in the sump improve
		Shut off valve in the suction line in unfavourable position	In suction line, foot valve is also called shut off valve, if it is left half-open, pump will not deliver water fully. The shut off valve seat and flap may be leather make or brass metal or rubber. Remove the foot valve from the pump suction pipe and check for leakage if it is damaged, replace the shut of valve.
		Valve in the suction line not fully open	Pump suction line is provided with a valve. This valve should be fully open for satisfactory operation of pump. Make sure that the valve is fully open. This can be checked by hydraulic for leakage.
		Joints in the suction line not leak-proof	Pump suction line flange joint to be replaced. Valve and foot valve nut bolts to be tightened and joint to be replaced, section pipe to be checked by hydraulic for leakage

		Air leaking through the suction line & stuffing box etc	Air leakage through suction pipe must be checked through joint or through pipe hole. It may be from the pump stuffing box. If pump gland leakage is more, replace the gland packing and take trial.
		Impeller partially clogged	Disconnect the pump suction line remove the pump volute. Check the impeller. If it is clogged with mud, sand, leaf etc, clean it. Fit the volute and suction line back with new joint packing, and take trial.
		Number of revolutions low	Decouple the motor, check the electric motor RPM. If it is low, check the electric supply or replace the electric motor with correct RPM. RPM can be measured by using a tachometer.
		Impeller damaged	Disconnect the suction line. Open the pump volute, check impellers if it is damaged, replaces the impeller with new one. Fit the volute back with the new joint and connect the suction line & take trail.
		Casing rings worn out	The wear out parts needs to be replaced and complete overhauling to be carried out.

		Pump unsuitable for parallel operation	If two pumps are running parallel then it is to be separated, individual suction line and delivery line connected to each pump separately
		Type of pump unsuitable	Refer the matter to pump manufacturer /supplier
		Incorrect choice of pump for existing operating conditions	Refer the matter to pump manufacturer/supplier
		Too many bends in the suction line	Suction line should be as straight as possible, fabricate suction line as per design.
		Clearance around suction inlet not sufficient	Sufficient free space is required around inlet of suction pipe for unobstructed entry of water, if sufficient space is not available provide the same.
3	Delivery Performance deteriorates with time after correcting the situation	Suction pipe, foot valve get choked often	Foot valve or suction is not placed in proper environment. In the sump or well lot of foreign material is present which is entering in the suction line or getting collected at the mouth of foot valve and preventing free entry of the water. Place the pump suction in the cleaner environment. Place a wire mesh at around the suction inlet after leaving suitable open space.
		Impeller getting clogged	Foreign material like leaves grass, mud sand etc are entering the pump volute. Provide strainer on the suction line and regularly clean it.

		Casing rings getting worn out	The wearing out of casing rings after sometime is normal but if it is occurring frequently the operation conditions are required to be looked into and matter should be referred to pump manufacturer/supplier
		Impeller getting damaged	Pitting or other damages are observed on impeller. If this is observed water quality requires to be checked. Presence of abrasive solids in the high rpm pumps may damage impeller and casing. If problem occurring frequently matter should be referred to the pump manufacturer/supplier.
4	Pump Delivers more than rated	Number of revolutions of motors are higher than the design revolution of pump	Replace the motor as per the pump RPM
5	After stopping pump runs in reverse direction	Non-return valve not functioning properly	Correct the position of the valve as per arrow mark on the body, if not correct. Replace the NRV if defective
6	Unsteady running of pump	Impeller clogged	Disconnect the pump suction line remove the pump volute. Check the impeller. If it is clogged with mud, sand, lead clean it. Fit the volute and suction line back with new joint, and take trial.
		Insufficient lubrications of Bearings	Stop the pump & lubricate the bearing by grease or oil as per pump supplier chart
		Specified oil level not maintained	Check for oil leakage. If oil leaks through oil seal, overhaul the pump, replace the oil seal, and add fresh oil.
		Bearing worn out	Pump to be overhauled and replace the bearing
		Oil/grease quality unsuitable	Oil/grease must be as per specified by pump manufacturer. Get right type of oil or grease and lubricate the bearings.
		Bearings dirty	Pump needs overhauling, disconnect the pump and dismantle, check the bearing if damaged replaces the bearing and fresh lubrication is to be done.
		Bearings rusty (corroded)	Pump needs complete overhauling disconnect the pump and dismantle the pump. Check all the parts. Repair or replace the wear out parts and bearing and lubricate it.
		Vibration of pipe work	Trace the source of vibration and remove it by giving it proper support.
		Obstruction in delivery line	Check up the delivery line gate valve and non-return valve for proper opening and closing operation.

		Ball bearings in correctly fitted	Pump needs complete overhauling disconnect the pump and dismantle it and check the bearing fitting and fit it properly in the bearing housing assemble the pump
		Shaft runs untrue	Remove the pump, dismantle the shaft, check on lathe machine for trueness, if it is bent replace it.
		Shaft bent	Remove the pump, dismantle the shaft, check on lathe machine for trueness, if it is bent replace it.
		Alignment of coupling faulty or coupling worn out	Decouple the pump and motor. Check the alignment of both coupling, if disrupted correct the alignment. Check the coupling fitments on the shaft, if it is loose, replace it. Check the foundation bolt, loose bolt is to be tightened.
7	Pump is heating up and seizing	Obstruction in delivery line	Check up the delivery line gate valve and non-valve for proper opening and closing operation
		Gland tightened too much /slanted	After fresh gland is packed gland follower bolt must be kept loose & after starting the pump gland follower bolt must slowly tighten to keep drop wise leakage through gland. Gland follower is to be fitted properly.
		Insufficient cooling water supply to stuffing box cooling	In the stuffing box cooling water chamber, remove the pipe, clean the chamber. Check cooling water supply, if it is less then increase it.
		Packing incorrectly fitted	Stop the pump, remove the old gland packing & replace it by proper gland packing, correct size type cutting.
		Packing not suitable for operating conditions	For water duty, correct size type and make of gland packing is recommended by the manufacturer of the pump, same to be only used like (champion style make 2222 type 6mm 8mm and 12mm)
		Shaft sleeve worn in the region of the packing	Dismantle the pump, check the shaft and shaft sleeves, if it is slight worn out take the machine out, if it is over damage replace the sleeves along with the shaft assemble the pump, packed the fresh gland packing and take trial test.
		Shaft runs untrue	Remove the pump, dismantle the shaft, check on lathe machine for trueness, if it is bent replace it.
		Shaft bent	Remove the pump, dismantle the shaft, check on lathe machine for trueness, if it is bent replace it.

		Rotor parts touching the casing	Disconnect the motor and check electric motor rotor for dynamical balancing at rated RPM and while assembling check other part obstructing and touching the casing, it is to be thoroughly overhauled.
8	Bearing temperature increases	Specified oil level not maintained	Check for oil leakage. If oil leaks through oil seal, overhaul the pump, replace the oil seal, and add fresh oil.
		Insufficient lubrications of Bearings	Stop the pump & lubricate the bearing by grease or oil as per pump supplier chart
		Oil/grease quality unsuitable	Oil/grease must be as per specified by pump manufacturer. Get right type of oil or grease and lubricate the bearings.
		Ball bearings in correctly fitted	Pump needs complete overhauling disconnect the pump and dismantle it and check the bearing fitting and fit it properly in the bearing housing assemble the pump
		Ball bearings over-lubricated	Stop the pump drain the oil or remove the excess grease from the bearing with the clean cloth. Fit it back and take trail.
		Bearings dirty	Pump needs overhauling, disconnect the pump and dismantle, check the bearing if damaged replaces the bearing and fresh lubrication is to be done.
		Bearings rusty (corroded)	Pump needs complete overhauling disconnect the pump and dismantle the pump. Check all the parts. Repair or replace the wear out parts and bearing and lubricate it.
		Insufficient cooling water supply to stuffing box cooling	In the stuffing box cooling water chamber, remove the pipe, clean the chamber. Check cooling water supply, if it is less then increase it.
		Sediment in the cooling water chamber of stuffing box cooling	Remove the cooling water pipes, clean the pipe and cooling water supply tank and fit it back with the fresh water.
		Delivery flow too great	Refer the matter to Pump manufacturer/supplier
		Impeller clogged	Disconnect the pump suction line remove the pump volute. Check the impeller. If it is clogged with mud, sand, lead clean it. Fit the volute and suction line back with new joint, and take trial.
		Impeller damaged	Disconnect the suction line. Open the pump volute, check impeller if it is damaged, replaces the impeller with new one. Fix the volute back with the new joint and connect the suction line & take trail.
		Casing rings worn out	The wear out parts need to be replaced complete overhauling

	Axial stress on ball bearings (no axial clearance for rotor)	Pump needs complete overhauling disconnect the pump and dismantle it and check the pump clearances, adjust the clearance and assemble the pump.
	Alignment of coupling faulty or coupling worn	Decoupled the pump and motor. Check the alignment of both coupling, if disrupted correct the alignment. Check the coupling fitments on the on shaft, if it is loose, replace it. Check the foundation bolt, loose bolt is to be tightened.
	Elastic element of coupling worn out	Decouple the pump and motor. Check the alignment, correct it, check both the coupling fitment on the shaft, if loose the correct it, check the pin bush if damage replace it.
	Pump casing under stress	Disconnect suction, delivery line at pump nozzle line and valves to be given proper independent support should not rest on pump casing.
	Nominal diameter of suction line too small	Pump suction pipe diameter should be bigger than pump suction nozzle hence replace the pipe line so that pump will not starve.
	Rotor parts insufficiently balanced	Disconnect the motor and check electric motor rotor for dynamic balancing at rated RPM.
	Shaft runs untrue	Remove the pump, dismantle the shaft, check on lathe machine for trueness, if it is bent replace it.
	Shaft bent	Remove the pump, dismantle the shaft, check on lathe machine for trueness, if it is bent replace it.
	Incorrect choice of pump for existing operating condition	Refer subject to Pump supplier/manufacturer

15.13. Records

For each piece of equipment and machinery a record register should be maintained in which all records of the equipment such as servicing, lubricating, replacement of parts, operating hours (including cumulative) and other important data is entered.

Records of Quality of Water

Complete records of bacteriological and chemical analysis of water from source to the consumers tap point should be maintained and reviewed. Charts could also be prepared for the important characteristics of the water and any changes in these characteristics as compared to the standards must be taken note of.

Records of key activities of O & M

For planning future augmentations and improvements of a water works in operations, it is advisable to maintain certain key records such as daily and cumulative supply over the

years, number of connections of various sizes given and cumulative number of connections each month, water treated and the supply billed.

15.14. Staff Position

Appropriate charts indicating the standard staff for each of the unit of operations and maintenance and the staff actually in position (by names if possible) shall be maintained at each office for review.

Skill requirement for O & M of Water Supply Scheme

Applicability	Scheme Component	Skill Requirement For Operation and Maintenance	Remarks
Option I	<ul style="list-style-type: none"> Hand Pump Dug Well 	Mechanic trained for repair and maintenance of hand pumps	The person will be able to do day to day maintenance however for overhauling factory trained mechanic will have to called
Option II	<ul style="list-style-type: none"> Bore well with submersible pump Open well with centrifugal pumps Storage Tank 	Person passed Electrical wireman's / Mechanical course from ITI	The person will be able to do day to day O & M however for repairs pumps and motors will be required to be sent to workshop.
Option III	<ul style="list-style-type: none"> Bore well with submersible Open well with centrifugal pumps Elevated Reservoir Distribution Network 	Person passed Electrical wireman's / Mechanical course from ITI	The person will be able to do day to day O & M however for repairs pumps and motors will be required to be sent to workshop.
Option IV	<ul style="list-style-type: none"> Jack well / Intake well Horizontal / vertical centrifugal pumps Slow Sand Filter Elevated Reservoir Distribution Network 	Person passed Electrical wireman's / Mechanical course from ITI	The person will be able to do day to day O & M however for repairs pumps and motors will be required to be sent to workshop.
Additional Option	<ul style="list-style-type: none"> Centrifugal Pumps Raw water pipe line Slow Sand Filter Elevated Reservoir Distribution Network 	Person passed Electrical wireman's / Mechanical course from ITI	The person will be able to do day to day O & M however for repairs pumps and motors will be required to be sent to workshop.

15.15. Inventory of Stores

A reasonable assessment of the stores and spare parts of machinery required over a period of time say, for half a year one year or can be made and an inventory of the same prepared. Issues and replacement of store articles could be watched and procurement procedures laid down and supervise. The aim should be that any material required for replacement is available at any time for the maintenance.

15.16. Source and Intake Works

a) *Sanitary Survey*

Sanitary Surveys at regular intervals at field management levels and inspections at supervisory management level should be conducted. The catchment area of the source should be located on the maps. Potential sources of pollution observed in the catchment should be marked. The type of pollution e.g. industrial / domestic waste discharges, wastes of animal origin and agricultural run-offs should be determined.

The quality of such discharges has to be ascertained and its likely effect on water being drawn at source should be mentioned. Reports of such surveys should be promptly sent to the Pollution Control Authorities as well as water works authorities to promote corrective action. Procedure for monitoring of preventive action taken should be laid down and observed. An instant action plan for providing chlorination of raw-water should be available and brought into effect under such circumstances.

(b) *Measurement of Flow*

In cases of sources such as springs, rivers, canals, etc., there should be a permanent arrangement for recording daily flows near the intake works. Appropriate records in the form of graphs showing variation of flows in the source for each month in a year and for each year shall be maintained. Rain gauge stations should be established to record daily rainfall in the reservoir catchment's and appropriate rainfall records should be built up and compared with discharges / storages available. In cases of reservoirs, the regime tables for refilling and emptying of storages should be maintained for each year.

Trouble shooting procedure for tube wells

S.No	Observations	Investigations	Causes	Actions
1	Reduced yield and loss of pressure	a) Check water level while pumping b) Check pump shut off head c) Check motor for overhauling and rotation d) Check static water level (min 8 hrs recovery)	i) Motor overheating, rotation slow, low voltage, pump overheating ii) Pump efficiency low pump worn out iii) Pump not performing on curve, pump water level down	i) Check motor, pull pump, check for wornout bearing. Replace wornout part ii) Check water static level. If SWL is lowered, modify pump to new position. iii) If SWL is normal pull pump and rehabilitate well
2	Sand in discharge, loss of pressure, surface subsidence around the well	a) Check well design for conformity to geological conditions b) Check pump for wornout impellers c) Check well construction for conformity to design	i) Design unknown or inadequate ii) Well being over pumped iii) Pump is worn out iv) Casing failed	i) Correct faulty construction (repair casing or screen) ii) Repair or replace pump iii) Reevaluate option for new well and reduce yield of repaired well

S.No	Observations	Investigations	Causes	Actions
3	Well is surging, pump is cavitied, breaking suction, draw down excessive	a) Check pump discharge Vs. design inlet b) Check condition of well conduct pump test c) Check water levels in nearby wells	i) Pumping in excess of design rate ii) Drawdown in pumping well excessive, whereas SWL in observed wells is normal	i) Reduce pumping rate ii) Increase chemical quantities, repeat treatment, adopt vigorous surging. If still does not improve abandon well

15.17. Maintenance of Intakes

- It should be ensured that sufficient water level is maintained at head works in order to ensure drawal of required quantity of water into intake works without vortex formations.
- All intake strainers should be cleaned at frequent intervals particularly during monsoon to prevent entry of fish or floating matter into intake works.
- All damages to structural components of intake works particularly during floods should be promptly repaired.
- Sufficient stocks of rubble should be maintained at intake works site for use to temporarily overcome the problems of scours at spillways and other places.
- A schedule of painting of steel and other structural parts of the intake works should be prepared and followed scrupulously to avoid damages to the structures.
- All raw-water holding structures such as intake wells, jack wells and inspection wells should be desilted during and immediately after monsoon to remove settled silt.

15.18. Clear Water Sump & Reservoir

Roofing should be periodically checked to ensure that no leakages are there so that pollution can be prevented. Ventilator outlets should be regularly checked and cleaned to guard against mosquito breeding and bird droppings. Cleaning of the sump and reservoir should be done regularly. Level recorder should be kept in working order at all times.

The total capacity of clear water reservoirs should be adequate for storage of treated water, especially during low supply periods at night when reservoirs become full. Instances are reported, where water from the filters have backed up into the inspecting galleries, thus reducing the rate of filtration. The remedy lies in having additional clear water reservoir in the plant, or arrangement for the final water to be automatically pumped to the balancing reservoirs in the town.

15.19. Treated Water

The quality of the water before distribution may be controlled by adjusting the calcium carbonate balance in the water to safeguard against corrosion or excessive scale formation in pipes. The periodical analysis of the water can also indicate if there is any biological growth in the main and if any further chlorination is needed to check it. The samples of water collected from several points should be routinely examined for residual chlorine and other chemical and bacteriological parameters.

15.20. Balancing Reservoirs and Elevated Reservoirs

Important aspects to be considered during maintenance are:

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- (i) Measurement of inflows & outflows: Whenever measuring devices are provided, it should be seen that discharge at inlets and outlets fairly tally. It should be seen that water level indicators and recorders are in proper working order.
 - (ii) Structural Leakages: All structural damages and leakages should be promptly repaired.
 - (iii) Preventing External Pollution: The manhole opening, ventilating shafts and overflow pipes should be properly closed and protected from external pollution.
 - (iv) General cleanliness in and around the reservoirs should be maintained and observed. A garden around the reservoir structure may be provided.
 - (v) A programme for periodical cleaning of the reservoirs atleast once in a year should be undertaken. During such cleaning process there should be facility to by pass the supply to distribution system.
 - (vi) Appropriate safety measures to prevent climbing of unauthorized persons should be provided. All the railings provided shall be maintained in a safe and firm condition.

15.21. Maintenance of Water Treatment Plants

The engineer-in-charge responsible for maintenance of water treatment plants should have complete knowledge of the working of various components of the treatment system. Major problems in the treatment unit arise because of the fluctuation in quality and quantity of water, improper functioning of several units and mechanical and electrical equipment.

For proper and sufficient maintenance of treatment plants it is imperative to take timely action to avoid unexpected break downs. For effective maintenance the following points are to be observed.

- (1) Complete set of drawings of the components of treatment plant unit should be readily available. These drawings should indicate the location and sizes of all pipes and appurtenances.
- (2) The drawings of important parts of plant should be displayed inside the building of plant for ready reference.
- (3) A systematic routine schedule for inspection of various components of the plant and equipment installed in it, should be drawn and proper record should be maintained in respect of machinery and lubricants used.
- (4) A log book should be maintained keeping complete record of various units and equipment regarding their cleaning, repairs, break-downs of particular component and the time taken for its repair.
- (5) Analysis of water, Jar test records and the quantity of chemicals used should be maintained regularly and methodically.

Water treatment components

- a) *Chemical Feeders:* Alum tanks should be painted annually. Stock for spares, mixing devices should always be available.
- b) *Flocculation System:* The flocculation equipment should be checked up prior to monsoon once a year for overhauling and maintenance. The parts moving under water shall be dried, lose rust or scale removed and equipment should be thoroughly checked up to avoid break down during service, Sludge lines should be kept free from choke. The traction wheel should be checked for alignment.
- c) *Sedimentation Tanks:* The tanks should be checked up once a year and any minor repairs if required should be carried out. The walls and floors of the tanks should be thoroughly cleaned to remove algae growth or other loose material and dirt and then tank should be disinfected . Algae grown on walls of sedimentation tanks can be

controlled by coating the wall portion from FSL to a point 0.6 m below with a mixture of copper sulphate and lime. The sludge can be removed by opening the scour valve provided in the bottom of the tank. Sludge will flush with discharge of water with sufficient force. The sludge at the distant corners should be flushed towards the drain with the help of 65 mm dia hose streams with a pressure of 3.4 to 4 kg/cm².

d) *Filtration*

- i. *Slow sand filters*: Filter operation and maintenance, initial commissioning of filters, filter cleaning, resanding and flow control are discussed below. The inlet float valve should be periodically checked to maintain the desired valve of water over the sand bed.
- ii. *Rapid Gravity Filters*: The process of washing of filters with different methods such as High Velocity Wash Water System, Surface Wash System, Air Wash System, Application and Operation of filters, Filter Appurtenances such as rate of flow controller, such expansion gauges, care of sand in filter beds, chemical treatment etc.

The rate of flow gauges and loss of head gauges usually get out of order. Necessary spares for these gauges should be kept in stock for carrying out minor repairs quickly.

- e) *Chlorinators*: Whenever chlorinator goes out of order it should be repaired immediately and commissioned. It is necessary to dismantle gas piping and feeders once a year to clean the accumulate impurities to avoid unscheduled breakdown.
- f) *Records*: The format of records for the purpose of treatment would depend upon the size and type of treatment plant. The record should be kept systematically and regularly. Where the plants are large, each operator of the plant should maintain record of his own shift of 8 hours, recording hourly the chemical doses and volume of water treated etc. This information should be transferred to daily forms.

The laboratory assistant shall maintain records of laboratory tests indicating the volume of each sample, volume of reagent used supported by details of computations so that it can be rechecked by the engineer incharge in case of any variation. The record of chlorine equipment should indicate the volume of water treated, dosage of chlorine, loss of weight of chlorine cylinder (i.e., the actual amount of chlorine consumed) residual chlorine determined at specific intervals with column for remarks for indicating any particular observation or events

15.22. Slow Sand Filter

At start up filters is filled with water by introducing it from the bottom. First, close the outlet valve and change the filter with clear water from the bottom to remove the air bubbles from the filter bed. This method of filling should be continued till the water comes above the media at least up to 500 mm. This will prevent disturbance of bed that may be caused by turbulence on admission of raw water. Now open the inlet valve and start filling up the filter from the top up to the supernatant level. Open the outlet valve and waste the effluent. Continue wasting at a rate of approximately one quarter of the normal filtration rate till the filter gat mature.

The new filter takes some time to “mature” (to build up the “schmutzdecke” (a thin layer formed on the surface of the filter bed which contains algae, plankton, bacteria and other

forms of life and the sticky layers round the sand grains). Till maturing, the effluent quality is not expected to be satisfactory hence it is to be wasted.

For several weeks during “schmutzdecke” development the filter should be operated with the regulating valve only slightly open or fully closed. Subsequent to maturing the valve is gradually opened a little each day; to compensate for the choking of the filter and to maintain the required rate of flow. In the early part of the filter run the daily build-up will be almost negligible, calling for little valve adjustment but towards the end of the resistance will increase more rapidly, necessitating a more positive opening of the valve.

Regular Operation

After maturing filter will run without requiring much attention. Daily activities that an operator will have to pay attention are listed below in table

Daily Activity Chart for Slow Sand Filter

Activity	Procedure
1. Regulation of supernatant water level	Manipulate inlet valve to maintain a constant supernatant water level and to avoid overflow
2. Removal of scum and floating matter	Allow temporarily the supernatant with the scum to over flow or manually remove using long handled wire net
3. Checking the filtration rate	Observe flow indicator and note the rate if flow indicator is not provided try to calculate flow by recording the time taken in filling up the filtered water sump
4. Regulation of filtration rate	Manipulate filter outlet valve to maintain desired constant rate
5. Shutting-off the filter	Closing the outlet valve and inlet valve after days requirement of water is filtered

Cleaning of Filter

To clean the filter bed, (whenever required, normally once in two or three year) the raw water inlet is first closed, allowing the filter to continue to discharge to the clear water well as long as possible. Then by opening the waste valve on the effluent outlet pipe, the water level in the filter bed is lowered until it is 100 mm or more below the surface. Then a 10-20mm thick sand layer containing the “schmutzdecke” is removed using flat nosed shovels.

After the removal of the scrapping the bed should be smoothed to a level surface and restarted with sand topping up. The quicker the filter bed is cleaned the less will be disturbance of the bacteria and the shorter the period of re-ripening.

Filter units should be cleaned one by one. When one unit is cleaned others can be operated at higher rate to avoid shortfall of filtered water.

Schedule of Activities for Caretaker

A) Daily

- Check the raw water intake (some intakes may be visited less frequently)
- Visit the slow sand filters.
- Check and adjust the rate of filtration.
- Check water level in the filter
- Check level in the clear water well
- Take sample and check water quality
- Check all pumps
- Maintain the logbook of the plant. Record information in the format as given in Table

B) Weekly

- Check and grease all pumps, valves and moving parts.
- Check distribution network and taps and arrange repairs, if necessary
- Communicate with user public for problems if any in water supply
- Keep the plant-site clean

C) Monthly or Less Frequently

- Scrape the filter beds as and when necessary
- Wash the scrapings, dry and store the washed sand.

D) Yearly or Less Frequently

- Clean and disinfect the clear water well
- Check the filter and the clear water well for water-tightness.
- Check the condition of Filter, clear water well and other structure provide repair painting, etc if required.

E) Every Two Years or Less Frequently

- Check the filter sand quality, if mud accumulation is excessive and filtration rate is slower and water quality is not good, remove the sand wash and refill. Make up with fresh sand

15.23. Distribution System

Important aspects of operation and maintenance of distribution system are detection and prevention of wastage due to leakage. The object is to control the waste within reasonable limits.

- Pipe Lines and Storage Tanks:** The most important aspect in the maintenance of distribution system is the establishment of system maps and records. Leakage, its detection and remedial measures. The pipe lines should be flushed systematically through the hydrants and scour valves. Dead ends need special attention. The importance and methods of disinfecting newly laid or newly repaired pipes and disinfection of reservoirs and wells etc is discussed
- Meters:** Accurate metering is the key to maximize the operational efficiency of water supply systems. It ensures accurate billing, helps identify leaks and provides consumption data

which is vital for future planning. Water authorities all over the world are increasingly recognizing the importance of accurate metering for control, management and development of water supply. An effective maintenance of meters plays a vital role in the maintenance of distribution system. Meters indeed deserve a careful attention. These are perhaps the most delicate pieces of equipment and thus are most difficult to maintain. Skilled staff fully conversant with the maintenance of meters and necessary workshop is required to overhaul, repair and test water meter. A willful damage to water meters is a common phenomenon either due to dishonesty of consumers or due to corrupt practices of meter readers. It is necessary to manage effective maintenance of meters otherwise revenue will suffer very badly

Several types of meters are available in the market. Positive meters are more expensive and accurate. Their use is limited because of their prohibitive cost. These meters are capable of measuring every drop of water passing through them either by displacement of piston inside the cylinder or a smaller cylinder revolving eccentrically inside another. In case where accuracy of measurement of varying flow or small flow is intended, positive meters are particularly suitable. Inferential meters work with water passing through which spins a metal or a plastic wheel fitted with blades in the meter. The speed of the moving wheel varies with variation in flow of water passing through the meter. The number of revolutions of the wheel are transmitted the dial face through the system of gears. The accuracy of revolving cylinder provided in positive type meters is more than the accuracy of fan or wheel provided in inferential type meters.

- c) **Cross Connections:** It is very important to ensure that no direct connection is made from the water distribution main to the industrial storage tanks for storing the untreated or polluted water, scour lines and unfiltered water supplies etc. Care is needed to locate scour points in the distribution system at safe points above the surface waters to prevent entry of surface water into the distribution system.

Special care is needed for connecting water closets, lavatory wash basins and urinals etc with public water supplies to eliminate the danger of back syphonage of contaminated water from sanitary appliances. Plumbing fixture should have necessary provisions against back syphonage otherwise in case of negative pressure in the pipe line caused by a burst in the system, fire demand, contaminated water will enter the distribution line resulting in public health hazard.

Under no circumstances cross connections shall be permitted. In case of requests from the industries to connect their line with public distribution system, it should be closely examined by the public health engineer. In case there is any likely hood of back-siphonage, a free fall discharge of water from distribution system should be ensured. Usually a free fall equal to at least two pipe diameters above the Full Supply Level of the receiving units is considered safe. Back flow preventers of approved design are also sometimes installed.

- d) **Continuous Service:** A good water system should provide uninterrupted supply. Intermittent supply due to shortage of water is most unfortunate practice from view point of health of consumers and the inconvenience involved. No system of water supply is water tight. The practice of intermittent supply of water produces negative pressure in the distribution system which leads to the entry of contaminated water from surface waters, drains and sewers etc., In view of shortage of water, during non supply hours, system should be kept charged. Under this system no time is lost filling water mains if fire takes place

outside the supply hours. Pressure can be built up in a matter of minutes and negative pressures are also avoided.

- e) **Dead Ends:** many distribution systems have dead ends. This is more so in case of distribution system in hilly towns because the ends of the distribution line cannot be connected due to topographical conditions. Because of the dead ends there is no free circulation of water. In the absence of free circulation of water it is not possible to maintain free residual chlorine throughout the distribution system. The maintenance engineer should make it a practice to flush all such mains through the fire hydrants and scour valves at regular intervals.

Further in case of intermittent supply, possibility of pollution of empty pipelines cannot be ruled out. Special inspection of pipelines through marshy or high water table areas, crossings across waste channels, pipes, etc., and in the vicinity of seers should be carried out regular intervals. Such areas should be identified on plans and bacteriological tests of tap water in such areas need to be done more frequently and results compared.

A regular programme of leak detection should be undertaken for the entire distribution system such that each section of the system comes up for leak detection atleast once in three years. Leaks and damages detected should be promptly repaired. The causes of wastage through leakages such as (i) high pressures in distribution, (ii) corrosive soils, (iii) corrosive water, (iv) inferior quality of pipes and fittings, (v) age of pipes, (vi) gland packings of valves etc., should also be ascertained. The repair work should tackle those causes as well.

In a distribution system complaints are received frequently from consumers about

- (a) Non-availability of required quantity of water
- (b) Low pressure at the supply point
- (c) Leakages & wastages through valves & pipelines
- (d) Unauthorised connections.

One of the major causes of wastage is unauthorized connections. Procedures for granting connections need to be streamlined. The officer incharge of operation and maintenance of distribution system should have powers to inspect any household for water supply to know as from where that household is taking water.

The entire distribution system could be divided into sub-zones served preferably from one elevated service reservoir. The maintenance and operation of each zone of distribution system should be entrusted to atleast a junior engineer who should be made the authorized official of the controlling authority to receive and deal with the complaints. Appropriate registers should be maintained by him to record the complaints and to note in it the follow-up action till the complaint is redressed. If the complaint is such that it cannot be dealt with at his level, he should at once refer the matter to higher authorities under intimation to the complainant. Frequent vigilance checks in the areas having maximum complaints should be made a part of the duty of the supervisory staff.

It is preferable to have meters provided by the water works controlling agency after charging appropriate monthly rentals to the consumer. This enables effective control over defective meters. Meter repair workshops should be established to attend to repairs of meters promptly. Surface boxes and chamber cover of valves should be frequently inspected and kept in proper condition. Billing for an out of order meter for more than three times consecutively should be avoided. All attempts should be made to repair / replace out of order meters once these are detected.

Sufficient stock of meters and spares should be available at hand to keep almost every meter in the field in working order.

Comprehensive water rules should be framed to make the maintenance operation most effective.

The consumers should be made aware of difficulties and shortcomings in the maintenance and operation of water supply system. Adequate publicity and public relations are required to be developed for this purpose.

15.24. Maintenance of the Valve

Common problems observed in valves and corrective actions for the same are given below in Table 15.1.

TABLE 15.1

Problem	Probable cause	Remedies
Water passing in closed valve position	Valve may not close properly	Open the valve and again close it and check ,if persists replace
Gland leaking through gland follower	Gland follower bolt must be loose	Tighten the gland follower bolt. Replace the gland packing
Valve is stuck up and not opening and closing	Valve gate must have stuck up. Valve spindle damaged	Remove the valve from the line & check for break down change spindle if broken
Valve leaking through bonnet joint	Joint damaged	Remove the valve and replace the bonnet joint
Valve while opening and closing slip down	Valve set nut or spindle threads are damaged	Remove the valve, check for break down and replace the spare parts

Procedure for overhauling of the Valve

- Disconnect the valve from the line
- Check for opening and closing
- Note the operation problem.
- Dismantle the valve
- Check all the parts
- After dismantling clean all the parts properly
- If any part is damage then replace it with new one

After overhauling is complete, assemble the valve properly while doing so apply grease to the moving parts. Put new gasket between valve body and bonnet provide new gland packing. Check the valve opening & closing, take the trial by placing in line.

15.25. Rain Water harvesting Structures

Rainwater harvesting systems require minimal attention with respect to their operation. Contamination of water as a result of contact with certain materials can be avoided by using appropriate materials during construction, or selecting tanks made from acceptable materials. The major concern is to prevent the entry of contaminants into the tank while it is being replenished during a rainstorm. Bacterial contamination can be minimized by keeping the rooftop surfaces and drains clean. The main causes of bacterial pollution are from debris, bird and animal droppings, and insects that enter the tank.

The following maintenance guidelines should be considered in the operation of rainwater harvesting systems:

- Water from the first rain shower not to be collected in the tank.
- Check and clean the storage tank periodically. All tanks need cleaning, and their designs should allow for the thorough scrubbing of the inner walls and floors using a chlorine solution (followed by thorough rinsing). This sometimes can be difficult to accomplish without emptying the tank.
- Cover and ventilate the tank to avoid mosquito breeding, prevent insects and rodents from entering the tank, and minimize the growth of algae.
- Chlorinate the storage tanks as necessary if the stored water becomes contaminated using slow-release chlorine tablets.
- In some cases, where the water is pumped, periodic, preventive maintenance is required on i.e., small pumps that lift water to selected areas of a house or building, or provide public supply from underground storage tanks, more-often-than-not, however, only repairs after breakdowns are done.
- Additional requirements for ground catchments include fencing the paved catchment to keep out trespassing animals (primarily small livestock such as goats, cows, donkeys and pigs) that can affect water quality, cleaning the paved catchment of leaves and other debris, and repairing large cracks in the paved catchment that result from soil movements, earthquakes, and/or exposure to the elements.

15.26. Materials Required for Maintenance

(a) Fuel: In rural water supplies where electricity is not assured, petrol or diesel engines to run the pumps are installed. Sometimes in urban areas also oil engines are installed as standby for use in the event of failure of electricity supply or for repairs etc., In case of small engine driven pumps, which are generally inefficient for many reasons, have high fuel consumption. As a guide, a small diesel engine will consume about 0.23 litres of diesel oil per hour per horse power and a petrol engine about 0.30 litres of petrol per hour per horse power. An electric motor consumes 0.746 kilo watts (units) per hour per horse power. The consumption of lubricating oil in a machine in good condition is approximately 0.067 of the fuel consumption of diesel petrol.

Care is required for the storage of petrol and diesel oil to prevent any loss due to fire or theft. Locking arrangement for the storage of fuel is, therefore, necessary. In case of small plants fuel is stored in drums in fire proof store room and it is taken by a litre measure to the fuel tank of the engine. In case of large plants, fuel is stored in underground tanks. Fuel is drawn from these tanks by means of a pump which has a locking arrangement.

The drums are placed in horizontal position on racks at a convenient height above the floor to allow the litre measure to stand on the floor below the tap of the drum. The diesel leaves some sediments at the bottom which have to be thrown away when the drum is nearly empty. If this is not done; the best of quantity of diesel in the drum carrying large amount of sediments in it will clog the filters or injectors of the engine. In case of petrol some amount of fuel is lost in evaporation despite all precautions taken in storage and handling.

(b) Chemicals: The most common form of chlorine used in urban areas is gaseous chlorine in cylinders and in rural water supplies, it is either bleaching powder (chloride of lime) or High Test Hypochloride (HTH).

The bleaching powder is supplied in drums, or in bags with polythene lining. It should be stored particularly in dry cool place.

Like all other materials, a careful check is extremely necessary for the quantity of bleaching powder issued and the balance available of bleaching powder issued and the balance available in the store. Minimum quantity of stock should be specified and order for new supply should be placed when minimum level of stock is reached. The aim should be that any material required for maintenance is available at any time.

The use of bleaching powder and HTH is quite irritating when comes in contact with eyes. Eyes should be washed with plenty of water in such a case.

(c) Tools: Minimum number of tools required are necessary for the proper maintenance of machinery and other equipments. The tools usually required are various sizes of spanners, hammers, axes, chisels, screw drivers, pliers, oil cans, fuel measures, grease guns, shovels, pans, picks, crow bars, chemical measure, water cans, buckets, chain pulley blocks, ropes, set of shear legs and a balance for weighing chemicals etc depending upon the type and requirement of equipments. In large installations over head traveling crane is provided inside the pump house for the purpose of maintenance.

A rack should be provided on the wall to hang various tools.

(d) Spare Parts:

In order to carry out effective and speedy repairs during the break downs of machinery and treatment plants, it is necessary to maintain a good stock of spare parts. To build up stock of spare parts would depend upon the type of equipment, location of installation, manufacturer's recommendations and according to the difficulty and time involved in arranging spares from local sources. It should be a practice to replace the spares after its use at the earliest.

The spare parts should be arranged as recommended by the manufacturer, usually required for a period of first two years. A complete record of spares should be displayed inside of the almirah, rack where spares are kept. When any of the part is used, it should be recorded and an effort should be made to replace the same immediately. The following details of spare parts can serve as general guide line for arranging the spares.

(i) *For Pumps:* Belt and belt fasteners, grease nipples, cup washers, gland packing, bearings, neck rings, neck bushes, sleeves, sleeve nuts, glands, logging rings, balance valve seating and bushes for three years operation and one rotation element (impeller assembly) for five years operation is required to be kept in stock.

(ii) *For Electric Motors:* The recommended spares for a squirrel cage motor are one set of bearings, part stator coils, insulation tape and sets of fuses; and for slip ring motor, one set of bearings, one set of carbon brushes and part stator coil and rotor bars are required to be arranged in stock.

(iii) *For Diesel Engines:* Gasket sealing compound, gaskets, set of injectors, washers, filter elements, fuel pipe, timing chain etc.,

(iv) *For Petrol Engines:* Gasket sealing compound, gaskets, sets of plugs, spare magneto, petrol feed pipe, air and oil filter elements, carburetor float, spare washers for petrol feed pipe and carburetor timing chain etc.,

(v) *For Distribution System:* The spares required for distribution system cannot be defined fully. Depending upon the size and type of pipes used in the distribution system, as a general guide a minimum half a dozen pipes of each diameter, type of joints used, (flanges,

detachable joints) lead, lead wool and yarn etc. for equal numbers of joints along with specials of each size such as bends of various degree, tees, collars, split collars etc., are required to be arranged. For molten joints, melting pot, ladle and a set of caulking tools are required. For cutting small pipes hacksaw and for cutting large pipes, special cutters are required. For thread joints of steel pipes, white lead, cotton threading, unions, stock and dies are necessary. Grease packing and glands are required for stuffing boxes. Tapping machine is required for drilling holes in cast iron pipes for inserting ferrules. Steel saddles are required for AC Pipes. Pipe wrenches and vices are required for steel pipes.

Like spares of machinery and equipment, it is necessary to order some percentage in excess of requirement in case of pipes and specials of distribution system to cover up the breakage during transit, handling and for maintenance also. The maintenance of distribution system and mains during the first few years of scheme's life is the heaviest. The trouble is more particularly in case of cast iron pipes and asbestos pipes. As already discussed, the minimum level of the stock of each item should be maintained and should not be allowed to fall below the particular figure of minimum level decided.

(f) First Aid Boxes: These are simple boxes for use by the staff in case of an emergency. This contains wound and burn dressing. Disinfectants like iodine is provide for small cuts with cotton for application of disinfectant. It is useful to have two scissors available in the first aid box for getting out splinters. In case of a wound, it should be thoroughly washed under clean running tap water and after that the disinfectant should be applied. In case of all major injuries and something effecting the eye, immediate medical help should be obtained. The patient should be immediately taken to hospital in case of fracture of bones and unconsciousness etc.,

(g) Miscellaneous Items: Certain miscellaneous items like lamps with a stock of kerosene oil, cleaning rags, brooms, soap, detergent powder, braso, three cell torch, emergency light, paint, paint-brushes, gardening tools and grass cutters are also required for carrying out maintenance job properly and effectively. Where bulk meters are used, daily and weekly charts and ink should be kept in stock for ready replacement.

Other items usually required are red hurricane lamps for warning traffic of an open trench, torches, valve keys, portable stand pipe and a lockable hand cart for carrying these articles from one site to another.

(h) General Cleanliness: Above all general cleanliness of plant is of vital importance. The equipment and the buildings where equipment is installed should be kept in neat and tidy conditions. This indeed speaks of the responsibility and the interest of maintenance personnel in the discharge of their duties. It can be safely said that if external cleanliness is neglected the internal maintenance and up-keep of the equipment which is not seen is neglected still more.

15.27. Health and welfare of water works maintenance personnel.

It is very necessary that the persons engaged in the operation and maintenance of water works, who come into contact with water supply works, who perfectly free from communicable diseases. Most of maintenance personnel come in direct contact with water such as labourer cleaning the filter boxes, cleaning tanks and wells, pipe fitters making repairs to the pipe line. So no labourer suffering from any disease should ever be employed on such

maintenance jobs. It is important to get the water works maintenance personnel medically examined periodically.

The water works area should be properly fenced and entry should be restricted. Water works site should not be allowed to be a thoroughfare otherwise people will use tanks for bathing, washing of clothes etc and start dumping refuse in the water works area.

Further it is necessary to provide accommodation to the operators and other maintenance personal near the water works. This way staff will be readily available in case of emergency.

It is advisable to provide a small room attached with pump house for use by the operators for taking meals and keeping their clothes etc., failing which the operators will use the pump house for this purpose. Nearby the pump house facility of water tap and water closet should also be made available, otherwise the operating staff will get water for drinking and cleaning food containers by dipping their utensils in the water tank itself. In the absence of water closet, the staff will spoil the surroundings by indiscriminate urination. All these things take place if proper attention is not paid to provide necessary facilities to the operating staff.

15.28. O & M of Single Village Schemes (SVS).

1. Collection of water tax: At present in some villages no tax is collected for village water supply scheme. However it is necessary that taxation proposals are brought in, so as to recover full cost of maintenance including depreciation, special repairs etc. For standposts, general water charges can be levied. For house service connection, additional water tax can be levied, so as to make the scheme self sufficient.
2. Operation and Maintenance cost recovery includes the following
 - i) Cost of operation(cost of Salaries, electricity and chemicals)
 - ii) Cost of Maintenance (Cost of spare parts, burst pipes, regular servicing, up-keep of buildings, replacement of worn-out parts)

The Village Panchayat/ GPWSC should decide and enforce water tariff to be collected from the users.

3. Guide Lines to be followed by the village panchayat/GPWSC for operation and maintenance
 - Prepare, revise and table the bylaws for approval by the Grama Sabha
 - Monitor the adherence to the water supply bylaws
 - To fix water tariff for House Service Connections and public stand post
 - Open a separate bank account for O&M
 - Prepare Annual Plan for the O&M of SVS.
 - Prepare Long Term Plan for future expansions.
 - Establish and maintain a proper transparent revenue, collecting systems.
 - Maintenance of scheme in efficient and smooth manner
 - To keep adequate spare parts in stock
 - To monitor the functioning and status of water supply
 - To check regularly that all water supply installations are functioning well
 - To respond and take immediate action on the consumer's complaints.
 - To maintain cleanliness around water sources, pump room, OHSR and stand post locations to avoid contamination.

- To create awareness among beneficiaries about the benefit of the system and the need for proper maintenance of it.
- To maintain good public relations and rendering satisfactory service to the consumers
- To maintain quality of water to desired standards.
- To collect revenue for sale of water to private persons for functions etc.
- To maintain efficient administration and communication system
- To conduct monthly GPWSC meeting.

4. Duties of pump operator

- The Pump operator should check all the components periodically for better maintenance of scheme
- Checking of quality and quantity of water supplied to all consumers (especially tail end taps)
- Keep the pump room inside, outside and OHSR premises neat and clean
- Clean the Panel board and check the oil level in oil starter if provided periodically.
- Maintain a log book showing the hours of pumping, energy meter reading, voltage meter and Ammeter reading, Power Supply interruption, water meter reading and repair details clearly.
- Maintain a register of works/repairs carried out
- Operate the pump set regularly
- Replacement of gland rope and applying grease periodically
- Checking of gate valves, pressure gauge and reflux valves fixed at pumping station and gate valves at OHSR
- Attend leaks in pumping main, distribution main valve pits and taps regularly
- Clean the OHSR periodically and chlorinate the OHSR water before distribution.
- Assist the GPWSC in protecting the water sources and carrying out water quality tests.
- Adhere to the instructions from the village panchayat/GPWSC
- Informing the problems then and there to the GPWSC
- Participate in the GPWSC meeting regularly for expressing the water supply position and problems being faced.

5. Licensed plumber functions

- To effect House Service Connections as directed by the GPWSC for the consumer
- Should have proper tools
- Should not give connection from the existing stand post or on the Pumping Main.
- Should not resort to undue favour in giving House Service Connections.
- Should provide hole on top of distribution pipe to fix the saddle piece and should not entertain to provide connection from bottom of pipe.
- To refill the trench after finishing repair or installation works.
- To attend the leaks and bursts occurred in pipe lines, valve pits etc. then and there to avoid wastage of water and to refill the trench after finishing repair works.
- To eliminate pit taps and to initiate action against the people who draw water from Public Fountains without taps.
- To check the water meter fixed to the House Service Connections.
- To scour the Pipe lines of both Pumping Main and distribution main periodically

- To check the valves and unauthorised House Service Connections regularly
- To obey the instructions of GPWSC

6. Common Problems in water supply

Problems	Reasons
1. Source Failure	1. Silting up of bore well 2. Casing pipe damaged 3. Motor/Pipes dropping inside the tube well 4. Not a potential source 5. Insufficient yield (Especially in Hard rock areas,) 6. Quality problem
2. Bore well with High turbidity & Excess iron.	Developing of the bore well not done properly..
3. Pump room in a damaged condition	Due to poor maintenance
4. Pumpset efficiency gone down	Due to normal wear and tear
5. Discharge problem	Improper selection of pumpset and installation not at optimum pump setting depth.
6. OHSR leaky & concrete peeling off, leaky Valves	Due to poor maintenance
7. Burst in Pipelines	1. Due to poor quality of pipes 2. Improper selection of size of pipes 3. Improper laying & jointing of pipes
8. Water does not reach certain pockets	(i) OHSR situated at low place. (ii) Tapping more water near the OHSR (iii) Water Supply system not regulated (iv) Distribution lines not laid in the newly developed area (v) More number of House Service Connections (vi) Improper tapping through pit taps (vii) Sufficient quantity of water not available
9. Damaged stand post & leaky taps	Due to poor maintenance.

Details of Problems Encountered and Remedial Measures to be Taken

The following remedial measures have to be taken by the GPWSC to ensure Water Supply to the Public

Component	Trouble shooting	Probable Reasons	Remedial measures to be taken
(a) Hard rock bore well	Discharges less water mixed with fine sand	Due to erection of motor below the lowest spring and also due to over pumping the water table falls down below the lowest spring. Hence yield reduces and causes silting	i) The pumpset may be removed immediately ii) Flushing may be done till discharges clear water. iii) Actual yield may be observed and erect lesser capacity motor to suit with the available yield and head required. iv) Additional bore well may be drilled to meet out the requirement.

	Source failed	Due to over exploitation of ground water by higher duty pumpset, water table falls down and thereby yield reduces	<ul style="list-style-type: none"> i) If possible hydrofracturing may be done ii) Rain Water recharging may be done near the bore well iii) If not suitable to carry out the above, compensatory bore well may be drilled.
		Due to damage of MS casing pipe Erosion of bore well below the casing pipe or at loose or boulder formation	<ul style="list-style-type: none"> i) Redrilling may be done to the required depth ii) PVC casing pipe may be provided for over burden earth iii) If Redrilling not possible, alternate bore well to be drilled
(b) Sedimentary bore well	Reduction of yield	Due to clogging of Slots	<ul style="list-style-type: none"> i) Chemical treatment using poly phosphate the clogging may be removed to increase the yield ii) High pumping should be avoided
	Discharges less water mixed with fine sand	Due to surging of bore well	<ul style="list-style-type: none"> i) Flushing may be done till discharges clear water ii) If silting is not noticed pumpset of lesser duty may be erected above the bottom most spring iii) If not possible to avert excessive silting, alternate bore well has to be drilled
	3.Quality problem	Due to excessive pumping saline water intrusion occurs	<ul style="list-style-type: none"> i) Not possible to use it immediately ii) Recharging of rainwater may be done near the bore well for reuse at later date if quality improves iii) Protection of source
	High turbidity	Flushing not sufficient Improper slots and pebble packing	Flushing may be done properly.
(c) Pump room	Plastering	Improper plastering and	Chipping, and re plastering.

	peeling out / cracks	curing	
	Pump room damage	Due to settlement of structure	i) New Pump room has to be constructed
	Sinking of floor	Due to improper consolidation	i) Flooring concrete should be removed ii) The soil filled up already may be watered, consolidated properly iii) Floor concrete may be laid

Operation & Maintenance Estimate for Single Village Scheme

Operation & Maintenance Cost of single Village Scheme at.....

1. Salary of operating staff

Pump operator cum Valve operator – 1 No or more

Rate @ Rs. Per month

Total amount per year (12 x Rs.) :

1. Energy Charges

No of units consumed per month

= $0.746 \times \dots \times \text{Pumpset HP} \times \text{Avg. pumping hours per day} \times 30$

= Units

Total amount per year

= $12 \times \text{Total consumed units per month} \times \text{power unit rate}$:

2. Bleaching powder for disinfection

Daily bleaching powder requirement (25% strength) in kgs

= $4 \times \text{quantity of water (lts)} \times \text{Chlorine dosage (1 mg/l)} \times 10^{-6}$

Total amount per year

= $365 \times \text{Daily Bleaching powder requirement(kgs)} \times \text{Rate per kg}$:

3. Annual maintenance and repairs

(a) 1 % on civil works cost of scheme :

(b) 5% on Mech. Cost of scheme (Bore well, Pumpset etc) :

4. Add 5% towards miscellaneous and unforeseen items etc. :

Total Maintenance cost

ANNEXURE-I Typical Contents for Preparation of Detailed Project Report

- Salient features
- Index maps
- Summary of cost
- Specification Report

1.0 Introduction and Background

- 1.1 District profile
- 1.2 Mandal profile
- 1.3 village profile

2.0 Existing water supply, sanitation, roads and drainage facilities

- 2.1 Water supply
- 2.2 Roads and Drainage
- 2.3 Sanitation
- 2.4 Water Quality Analysis

3.0 Population projection and demand assessment

- 3.1 Population projection
- 3.2 Demand Assessment

4.0 Design Norms

5.0 Identification of proposed source report

- 5.1 Field data of proposed water sources
- 5.2 Data of proposed ground water sources
- 5.3 Data of proposed surface water sources
- 5.4 Final Source selection
- 5.5 Geophysical survey
- 5.6 Water Quality of analysis
- 5.7 Artificial Recharge Structures

6.0 Proposed water supply scheme

- 6.1 Pumping machinery
- 6.2 Pumping main
 - 6.3 Water treatment plants
 - 6.4 Salient features of Service Reservoir
 - 6.5 Distribution System
 - 6.6 Soil Investigation
 - 6.7 Disinfection Unit

7.0 Land Requirement

8.0 Estimated Costs for water supply scheme

- 8.1 Cost of land
- 8.2 Establishment of sources
- 8.3 Pumping machinery
- 8.4 Transmission Main
- 8.5 Water treatment plants
- 8.6 Service Reservoir

-
- 8.7 Distribution System
 - 8.8 Operation and Maintenance costs
 - 9. Proposed Internal Roads and Drainage System**
 - 9.1 Roads
 - 9.2 Drains
 - 9.3 Estimated costs
 - 9.4 O & M of Roads and drainage system
 - 10.0 Proposed Environmental Sanitation**
 - 10.1 Estimated costs
 - 10.2 O & M Environmental Sanitation
 - 11.0 Analysis and design details**
 - 12.1 Economic analysis of raw water Pumping main and Design of pump set
 - 12.2 Design of Water Treatment plant
 - 12.3 Design of Distribution Network
 - 12.4 Design of Service Reservoir
 - 12.5 Design of Drains
 - 13.0 Data**
 - 13.1 Lead chart
 - 13.2 Quarry Maps (approved)
 - 13.3 Rate Analysis for General items
 - 14.0 List of Drawings**

2.1 Proforma for Existing Water supply

Sl.No.	Water supply components		Unit	Qty	Status
1.	Sources	BW with HP	No.		
		BW with PS	No.		
		OW	No.		
		OW with PS	No.		
2.	Technology	HP	No.		
		MPWS	No.		
		PWS-GW	No.		
		CPWS	No.		
3.	Storage	Cisterns/GLSR	No.		
		OHBR	No.		
		OHSR	No.		
		Sumps	No.		
4.	Water recharge structures	Earthen Bund	No.		
		Check dams	No.		
		Dykes	No.		
5.	Pump sets	Submersible	No.		
		Centrifugal	No.		

Sl.No.	Water supply components		Unit	Qty	Status
6.	Pumping main	CI/GI/PVC/AC/HDPE/PSC	M		
7.	Distribution system	CI/GI/PVC	M		
8.	Valves	Air valves	No.		
		Sluice valves	No.		
		Scour valves	No.		
		Non-return valves	No.		
9.	Stand post		No.		
10.	No. of house connections		No.		

2.2 Existing Roads and Drainage

Sl.No.	Description of the components		Unit	Qty	Status
1.	Roads	Earthen Roads	M		
		Burnt slab paving	M		
		Stone paving	M		
		WBM Roads	M		
		Asphalt Roads	M		
		Concrete Roads	M		
2.	Drains	Slab Drains	M		
		Pre-cast drains	M		
		Masonry drains	M		
		Earthen drains	M		

2.3 Existing Sanitation

Sl.No.	Description of the components		Unit	Qty	Status
1.	Habitat Development	Washing platforms	No.		
		Dust bins	No.		
		Smokeless chulas	No.		
		Biogas unit	No.		
		Compost pits	No.		
		Soak pits	No.		
		Cattle trough	No.		
2.	Sanitation	Ind. Sanitary latrines	M		
		Comm. Latrines	M		
		Institutional Latrines	M		

Existing condition of OHSR

OHSR	Cap	Stg. Ht	Column size	Branch-ing size	Soil condition	Column	Braces	Bottom slab	Side wall	Top dome

Riser Pipes	CI values	Stairs	Fencing	Valve chamber	Lighting arrestor	Water level Indicator	Conclusion/remarks whether to rehabilitate or to abandon

5.5 Details of Existing sources

Sl. No.	Description		Bore well with HP			Bore well with PP			Open Wells		Open Wells with PP	
			BW1	BW2	BW3	BW1	BW2	BW3	OW1	OW2	OW1	OW2
1.	Location with reference to permanent features											
2.	Year of drilling											
3.	Depth of drilling / OW											
4.	Dia of BW/ OW											
5.	Length of Casing pipe											
6.	Yield at the time of drilling											
7.	Year of commission											
8.	Qualit y of water	Potable										
		Potable with treatment										
		Non-potable										

Sl. No.	Description		Bore well with HP			Bore well with PP			Open Wells		Open Wells with PP	
			BW1	BW2	BW3	BW1	BW2	BW3	OW1	OW2	OW1	OW2
9.	Distance from nearest power source***											
10.	Pump House	Type										
		Location										
		Condition										
11.	Condition of Electrical installation											
12.	Avg. No. of hours of power supply in a day with req. voltage											
13.	Type of OW											
14.	Yield of existing source											
15.	Remarks											

5.6 Water Quality Data of Existing / Proposed sources

Sl. No.	Location of source	Type of source	Chemical Constituents	Turbidity	pH	TDS mg/l	Alkalinity mg/l	Residual free chloride	Nitrate mg/l	Chloride mg/l	Sulphide mg/l	Fluoride mg/l	Iron mg/l	Total Hardness mg/l	MNP Count/ 100 ml	DC Test E-coil
			Acceptable	1.00 Ntu	6.5-8.5	500	400	0.2	50	200	200	1.00	0.30	300	0	Absence
			Cause of rejection	10	No Relaxation	2000	>600	0.5	No relaxation	400	400	1.50	1.00	600	>10	No relaxation
		BW1														
		OW1														

5.8 Field data of proposed water sources

		Source-1	Source-2	Source-3
a)	Observation made from topo sheets			
b)	Observation made from satellite imageries based on interpreted maps			
c)	Observation made from Ground water maps prepared by Dept. of Ground Water			
d)	Observations made on reconnaissance			
e)	Observation made from water quality maps prepared by RWS&S			

5.9 Data for Proposed ground water sources

Sl. No.	Description of item	BW ₁	BW ₂	BW ₃	OW ₁
1.	Location with reference to salient / permanent features				
2.	BW/OW depth in mts				
3.	BW/OW dia in mm				
4.	Depth of Casing pipe				
5.	Yield lts/hr				
6.	Static water level in mts				
7.	Expected drawdown level				
8.	Percentage of yield to be harnessed				
9.	Ownership of the land				
10.	Quality of water				
11.	Special problem anticipated during drilling Boulder formation if so indicate depth, collapsible formation if so the depth in mts.				
12.	Any other precautions to be taken during drilling				
13.	Balance hourly total yield in lts/hr required for designed population				
14.	Hydro-geological condition				
	a) Geology of the area				
	b) Soil type / thickness				
	c) Weathering depth				
15.	Remarks				

5.10 Data of proposed surface water sources

Sl. No.	Description	Details
1.	Name of river basin	
2.	Name of main river	
3.	Name of tributary	
4.	Name of stream /nalla	
5.	Projected demand (2021) lts/day	
6.	Existing supply lts/day	
7.	Balance requirement lts/day	
8.	Hydro-geological conditions	
9.	Details of the Runoff of river/stream source	
10.	Location	
11.	Bed level	
12.	H.F.L.	
13.	Minimum stream flow	
14.	Maximum flood discharge	
15.	Quality of water	
16.	Depth of water pool at proposed tapping point	
17.	Soil characteristics of river or stream bank	
18.	Details of proposed jack well	
19.	Height	
20.	Type of construction	
21.	Diameter	
22.	Water treatment process	
23.	Distance from the source tapping point w.r.t. village location	

5.11 Final Source Selection

Sl. No.	Type of source	Drilled yield (lph)	Recommended safe sustainable pumping (lph)	% yield of harness	Daily demand (lts)	Daily supply (lpd)	Remarks
1.							
2.							
3.							
4.							

5.13 Pumping Machinery

Sl. No.	Source No.	Pumping (lpm)	Total head (m)	Pump setting level (m)	Valves		Pumping hours	Remarks
					GV	NRV		
1.								
2.								
3.								

5.14 Pumping main

Sl. No.	Segment	Length	Pipe material	Dia in mm	Pressure rating	No. of valves				Thrust block	Remarks
						AV	SV	SCV	NRV		
1.											
2.											

6.3 Salient features of proposed storage reservoir

Sl. No.	Storage Reservoir	OHSR1	OHSR2	GLSR
1.	Location			
2.	Capacity (litres)			
3.	Staging Ht. (M)			
4.	Bore wells connected			
5.	Inflow rate (lph)			
6.	Outflow rate (lph)			
7.	RL at GL of ELSR (M)			
8.	FSL (M)			
9.	HGL (M)			

6.4 Distribution system

Sl. No.	Length		Pipe material	Dia in mm	Pressure rating (KSC)	Peak Factor	No. of valves			Thrust block	Remarks
	Existing (m)	Proposed (m)					AV	SV	SCV		
1.											
2.											
3.											

6.5 Soil Investigation

Sl. No.	Identification of location	Soil Parameters		Type of soil at different depths
		SBC KN/M ²	Depth of foundation (m)	
1.	Service reservoir			
2.	Head Works			
3.	Raw Water Collection well			

ANNEXURE-II Design criteria for Water Supply Works

Per capita demand:

- Clear water : 40 LPCD
- Raw Water : 50 LPCD

Design period : 20 years

- Pumping hours : 20 hours
- Population growth rate : 1 %

Infiltration wells, raw water collection wells:

- Infiltration wells, raw water collection wells should be designed for ultimate demand.
- Dia and depth of the intake well will be governed by the no. of pump sets to be accommodated and stability of the structure.

Transmission lines:

- Transmission lines should be designed for ultimate demand.
- Approximate diameter of pipe : $0.76 \times (\text{LPM})^{0.46} \text{ cm}$
- Frictional losses:
Per 1000m : $607980 \times (\text{lpm})^{1.81} / (\text{d})^{4.81}$ in meters
where d = internal dia. of pipe in 'mm'

Maximum allowable friction losses = 1.5m /Km of pipe line

- CI pipes and DI pipes without cement
mortar lining increase the frictional losses : 34%

The minimum terminal pressure in the distribution system:

- At ferrule point : 3.0 to 6.0m (house service connections are not contemplated)
: 8.0 m (house service connections are provided).

Velocity in trunk mains:

- Minimum : 0.60 m/sec

One hand pump (or) stand post : 250 persons.

Summer Storage Tank:

- Summer Storage Tanks to be designed for ultimate demand and for canal closure period duly considering 20% percolation losses and 20% evaporation losses i.e total 40% losses.

Clear water Sumps: (to be designed for prospective demand)

- Capacity of sump (generally) : 2.5 hours to 4.0 hours
- 4.0 hours capacity sump may be provided at intermediate booster stations.

OHSR: (to be designed for prospective demand)

- Capacity of OHSR : 0.50 x (prospective daily demand)

OHBR: (to be designed for prospective demand)

- Capacity of OHBR (approximate) : 30 to 60 minutes depending on pipe net work.
- Capacity of OHBR shall be designed to avoid over flow/empty conditions during the pumping.

Break Pressure tanks (BPT): (to be designed for prospective demand)

- Break Pressure tanks are designed to minimize the abnormal static heads in the pipeline net work.
- Capacity of BPT (approximate) : 15 minutes
- To avoid over flow condition the capacity of BPT shall be designed as per the rate of inflow.

Pumpsets:

- Capacity of pump set : $(\text{LPM} \times \text{total head} \times 100) / (4500 \times \text{efficiency})$
- Efficiency
 - Submersible : 40%
 - Centrifugal : 60%
 - Vertical turbine : 70%
 - Horizontal split casing : 70%

Slow Sand Filters: (To be designed for prospective raw water demand).

- Rate of filtration : 0.1 m/hour
- Area required : $(\text{Prospective Demand in } M^3) / (\text{Hours of Operation} \times 0.1 + 0.5 \text{ m}) = M^2$
- Filter bed area : 5-100 sq.m, minimum of 2 units.

Where A = total surface area required.

Rapid Sand Filters:

- Rate of filtration : 4800 to 6000 liters/sqm/hour
- No. of beds : $(Q)^{0.5/4.69}$

Where Q = discharge in cum / hour

- No. of Units : Minimum of 2 units

(i) Aeration Fountain floor area required: 0.015 to 0.045 Sqm/Cum/hour

Stilling Chamber detention time : 60 sec

Mech. Flash Mixer

- Detention time : 30 to 60 sec
- Velocity gradient : > 300 / sec

Hydraulic flocculator

- Depth of Water : 3.0 m to 4.5 m
- Clear distance between baffles : 0.45 m minimum
- Velocity of flow : 0.10 to 0.3 mps
- Detention time : 20 to 40 minutes
- Velocity gradient : 10 to 75 / sec

Tube settling Tank

- Velocity through inlet pipes : 0.24 to 0.27 m/sec
- Detention time : Minimum 35 Minutes
- Depth of water : Minimum 3.0 M (above hopper top)
- Weir loading : Less than 300 cum / RM /day

(b) Clariflacculator

- Detention time in flocculator zone : 10 to 40 minutes, normally 30 minutes
- Detention time in clarifier zone : 2 to 4 hours
- Side water depth : 3.0 to 4.5 m
- Surface loading : 40 cum / sqm / day
- Weir loading : less than 300 m³ / RM / day
- Velocity of flow through opening in partition : < 0.1 m / sec.

Back Wash (with only water)

- For plant capacities : Below 5 MLD
- Rate of backwash : 800 lpm / sqm of bed area
- Pressure head in the under drain : 8.0 m
- Duration of back wash : 10 minutes.

Air and Water combined wash system

- For plant capacities : Above 5 MLD
- Rate for air wash : Pressure of 0.35 kg/cm²
- Duration : 5 minutes.

- Rate of back wash with water : 600 lpm / sqm of bed area
- Head : 8 m
- Duration : Minimum 10 minutes.

Chlorination

- Chlorine dose (Pre & Post chlorination) : 6 Mg / l
- Available Chlorine in bleaching powder : 25% (Min)
- Strength of solution : 5%
- Residual chlorine @ tap point : 0.2 mg / l

Alum solution

- Alum solution maximum dose : 50 Mg / l approximately
- Strength of solution : 5%
- Dosage of alum should be decided based on the Jar test carried out on the raw water.

Dia	Water hammer co-efficient of HDPE pipes (PE-80)			
	4	6	8	10
63	0.14190616	0.18601167	0.23469723	0.29011770
75	0.09653012	0.13124984	0.16487373	0.20303246
90	0.06727724	0.08983408	0.11332006	0.13998291
110	0.04496305	0.06005729	0.07594807	0.09218117
125	0.03444945	0.04610984	0.05844178	0.07183735
140	0.02723142	0.03650960	0.04635693	0.05710875
160	0.02087981	0.02798571	0.03530714	0.04359691
180	0.01636538	0.02197014	0.02796511	0.03436905
200	0.01317032	0.01782209	0.02256350	0.02778853
225	0.01041584	0.01399869	0.01775838	0.02191660
250	0.00844309	0.01134565	0.01440681	0.01772670
280	0.00668746	0.00899828	0.01144464	0.01411185
315	0.00530857	0.00710599	0.00904690	0.01113565
355	0.00415218	0.00558917	0.00709910	0.00875734
400	0.00337524	0.00457436	0.00584121	0.00723463

Dia	Water hammer co-efficient of PVC pipes		
	4	6	10
63	0.18543009	0.23433302	0.32104532
75	0.12855473	0.16123289	0.22725295
90	0.08841714	0.11155078	0.15387229
110	0.05709052	0.07213865	0.10460234
125	0.04413743	0.05674812	0.08044683
140	0.03514006	0.04468562	0.06378336
160	0.02673872	0.03389437	0.04894522
180	0.02129624	0.02710648	0.03846807
200	0.01696429	0.02197735	0.03122543
225	0.01345606	0.01724809	0.02468941
250	0.01073005	0.01399257	0.02000974
280	0.00864080	0.01117140	0.01594584
315	0.00681460	0.00883894	0.01253557

Dia	HDPE pipes															
	4 kg/cm2 (PE-80)				6 kg/cm2 (PE-80)				8 kg/cm2 (PE-80)				10 kg/cm2 (PE-80)			
	Min Wall Th	Max Wall Th	Wt (kg)	Internal dia	Min Wall Th	Max Wall Th	Wt (kg)	Internal dia	Min Wall Th	Max Wall Th	Wt (kg)	Internal dia	Min Wall Th	Max Wall Th	Wt (kg)	Internal dia
63	2.50	3.00	0.491	57.00	3.60	4.20	0.683	54.60	4.70	5.40	0.868	52.20	5.80	6.60	1.044	49.80
75	2.90	3.40	0.671	68.20	4.30	5.00	0.97	65.00	5.60	6.40	1.228	62.20	6.90	7.80	1.474	59.40
90	3.50	4.10	0.971	81.80	5.10	5.90	1.378	78.20	6.70	7.60	1.756	74.80	8.20	9.30	2.108	71.40
110	4.30	5.00	1.453	100.00	6.30	7.20	2.067	95.60	8.20	9.30	2.627	91.40	10.00	11.20	3.124	87.60
125	4.90	5.60	1.864	113.80	7.10	8.10	2.646	108.80	9.30	10.50	3.379	104.00	11.40	12.80	4.051	99.40
140	5.40	6.20	2.308	127.60	8.00	9.00	3.314	122.00	10.40	11.70	4.225	116.60	12.80	14.30	5.08	111.40
160	6.20	7.10	3.024	145.80	9.10	10.30	4.323	139.40	11.90	13.30	5.507	133.40	14.60	16.30	6.622	127.40
180	7.00	7.90	3.812	164.20	10.20	11.50	5.442	157.00	13.40	15.00	6.981	150.00	16.40	18.30	8.368	143.40
200	7.70	8.70	4.663	182.60	11.40	12.80	6.741	174.40	14.90	16.60	8.605	166.80	18.20	20.30	10.32	159.40
225	8.70	9.80	5.917	205.40	12.80	14.30	8.496	196.40	16.70	18.60	10.85	187.80	20.50	22.80	13.05	179.40
250	9.70	10.90	7.321	228.20	14.20	15.90	10.49	218.20	18.60	20.70	13.42	208.60	22.80	25.30	16.11	199.40
280	10.80	12.10	9.117	255.80	15.90	17.70	13.11	244.60	20.80	23.10	16.8	233.80	25.50	28.30	20.19	223.40
315	12.20	13.70	11.598	287.60	17.90	19.90	16.59	275.20	23.40	26.00	21.26	263.00	28.70	31.80	25.54	251.40
355	13.70	15.30	14.64	324.40	20.10	22.40	21.03	310.20	26.30	29.20	26.93	296.60	32.30	35.80	32.4	283.40
400	15.40	18.00	18.98	364.00	22.70	26.40	27.33	347.20	29.70	34.40	34.97	331.20	36.40	42.10	41.99	315.80

Dia	4 kg/cm2				6 kg/cm2				10 kg/cm2			
	Min Wall Th	Max Wall Th	Wt (kg)	Internal dia	Min Wall Th	Max Wall Th	Wt (kg)	Internal dia	Min Wall Th	Max Wall Th	Wt (kg)	Internal dia
63	1.50	1.90	0.468	59.20	2.20	2.70	0.666	57.60	3.50	4.10	1.01	54.80
75	1.80	2.20	0.655	70.60	2.60	3.10	0.923	68.80	4.20	4.90	1.439	65.20
90	2.10	2.60	0.924	84.80	3.10	3.70	1.321	82.60	5.00	5.70	2.032	78.60
110	2.50	3.00	1.323	104.00	3.70	4.30	1.902	101.40	6.10	7.10	3.062	95.80
125	2.90	3.40	1.722	118.20	4.30	5.00	2.511	115.00	6.90	8.00	3.929	109.00
140	3.20	3.80	2.144	132.40	4.80	5.50	3.116	129.00	7.70	8.90	4.905	122.20
160	3.70	4.30	2.799	151.40	5.40	6.20	4.012	147.60	8.80	10.20	6.414	139.60
180	4.20	4.90	3.581	170.20	6.10	7.10	5.134	165.80	9.90	11.40	8.092	157.20
200	4.60	5.30	4.331	189.40	6.80	7.90	6.351	184.20	11.00	12.70	10.001	174.60
225	5.20	6.00	5.511	213.00	7.60	8.80	7.975	207.40	12.40	14.30	12.675	196.40
250	5.70	6.50	6.674	237.00	8.50	9.80	9.886	230.40	13.80	15.90	15.686	218.20
280	6.40	7.40	8.453	265.20	9.50	11.00	12.4	258.00	15.40	17.80	19.616	244.40
315	7.20	8.30	10.682	298.40	10.00	12.40	15.72	290.20	17.30	19.90	24.732	275.20

water hammer Head in m

H max	=	$(C \times V_o) / g$
H max	=	max pressure rise in closed conduit above normal pressure in m.
C	=	Velocity of pressure wave travel in m/sec.
G	=	acceleration due to gravity in m/sec ²
V _o	=	Normal velocity in the pipeline, before sudden closure in m/sec
C	=	1425
K	=	Bulk Modulus of water 207000000 kg/m ²
C ₁	=	Walt thickness of pipe in m
E	=	Modulus of Elasticity in Kg/m ²
D	=	Internal dia of pipe in m

Modulus of Elasticity in Kg/m² (E)

Ac	3×10^9	3000000000
PVC	3×10^8	300000000
HDPE	3×10^7	90000000
RCC	3.1×10^9	3100000000
CI	7.5×10^9	7500000000
DI	1.7×10^{10}	17000000000
PSC	3.5×10^9	3500000000

ANNEXURE-III Design of Economic Size of Pumping Main

I. Basic data:

- | 1. Water Requirements | Year | Discharge |
|--|------|-----------|
| Initial (Base year) Scheme commissioning year | | |
| Prospective (I st Stage) i.e 10 yrs | | |
| Ultimate (II nd Stage) i.e 20yrs | | |
| 2. Length of Pumping Main (in mts) | : | |
| 3. Static Head for Pump (in mts) | : | |
| 4. Design Period (in years) | : | |
| 5. Combined efficiency of pump set (in %) | : | |
| 6. Cost of Pumping Unit (Rate per KW) | : | |
| 7. Interest Rate (in %) i.e 10% | : | |
| 8. Life of Electric motor and Pump (in years) | : | |
| 9. Energy Charges (Rs. Per unit) | : | |

II. Determination Total Head :

Total head for each stage for various alternative of pipes is the sum of Static Head, Frictional Head and other losses (10% of frictional losses).

III. Computation of Kilo Watts of pumpset :

$$\text{KW required} = \left(\frac{QH}{102} \right) \left(\frac{1}{\eta} \right) \left(\frac{24}{P} \right)$$

Q = Discharge at the end of (Ist Stage)

H = Total head in m for discharge at the end of Ist Stage

□ = Combined efficiency of pumping set

P = Hours of pumping for discharge at the end of Ist Stage

IV. Annual cost of Electrical Energy (CR):

$$CR = (KW_1)(\text{Average Hrs of pumping})(\text{Avg. days per year})(\text{Energy charges per KW})$$

Average hours of Pumping :

$$\text{For I}^{\text{st}} \text{ stage} = \left(\frac{\text{Hours of pumping for discharge at the end of 10 yrs}}{\text{Discharge at the end of 10 yrs}} \right) (\text{Average discharge})$$

$$\text{Average discharge} = \left(\frac{\text{Initial} + \text{Prospective}}{2} \right)$$

V. Pump Cost Capitalised :

$$P_0 = \frac{C}{(1+r)^n}$$

P_0 = Initial capitalized investment.

C = Amount required for the purchase of IInd stage pumps after 10 years.

r = Rate of compound interest i.e 10% per year.

n = No of years i.e 10 years.

VI. Capitalized Energy Charges (C_c) :

$$C_c = C_R \left(\frac{1 - (1+r)^{-n}}{r} \right)$$

C_c = Total amount to be invested in the beginning to realize annually the total energy charges.

C_R = Annual energy charges.

n = Period in years.

r = Rate of interest (10%).

ECONOMICAL PUMPING MAIN CALCULATIONS

Pumping main from :													
Name of the work:													
1	Discharge												
2	Life of pumpsets	10 years						Type of main WATER					
								Per capita supply: 55					
								Pop Growth rate: 1%					
3	Year of commission	3219 lpm	2009										
4	Prosp. Demand	3556 lpm	2019										
5	Ultimate demand	3928 lpm	2029										
6	Static Head	14.00 m											
7	Length of pipeline	4.50 km											
8	Cost of pumpset	10000 Rs./kw											
9	Efficiency	70 %											
10	Energy charges	4.50 Rs./kw											
11	Hours of pumping	20											
12	Avg. hrs. of pumping	19.05											
13	Interest rate	10 %											
14	Annual energy charge	20876.61 *KW											
15	Cap. Energy charges	6.14 *annual charges											
16	Capitalized Cost	0.39 *(cost of PS & energy charges of 2nd stage)											
SNo	Pipe Dia.	Inner Dia.	Velocity in m/s		Total head incl. Static head and losses in m				Power required and cost of				
			I stage flow	II stage flow	I stage flow	II stage flow	I stage flow	II stage flow	I stage flow	II stage flow			
			Static head	Static head	Static head	Static head	Static head	Static head	Static head	Static head	Static head	Static head	
1	200 mm	200 mm	189	2.08	68.83	82.83	14.00	82.41	96.41	103.13	103.13	132.60	
2	250 mm	250 mm	121	1.33	23.53	37.53	14.00	28.17	42.17	46.73	46.73	58.00	
3	300 mm	300 mm	84	0.93	9.79	23.79	14.00	11.72	25.72	29.62	29.62	35.38	
4	350 mm	350 mm	62	0.68	4.66	18.66	14.00	5.58	19.58	23.24	23.24	26.94	
5	400 mm	400 mm	47	0.52	2.45	16.45	14.00	2.94	16.94	20.49	20.49	23.30	
										Total			
SNo	Pipe dia	Total Head in mtrs	Class & type of pipe	Rate per m	Total cost of pipe in lakhs	I stage flow			II stage flow			Total cap cost in lakhs	
						Cost of Pumpset	Ann. Energy charge	Cap. Energy charge	Cost of Pumpset	Ann. Energy charge	Cap. Energy charge		
1	200 mm	96.41	AC	783.15	35.24	10.31	2153	177.84	13.26	27.68	170.09	70.69	248.53
2	250 mm	42.17	AC	1007.90	45.36	4.67	9.76	109.97	5.80	12.11	74.41	30.92	140.89
3	300 mm	25.72	AC	1407.00	63.32	2.96	6.18	38.00	104.27	3.54	45.38	18.86	123.13
4	350 mm	19.58	AC	1731.80	77.93	2.32	4.85	29.81	110.06	2.69	34.55	14.36	124.42
5	400 mm	16.94	AC	2293.70	103.22	2.05	4.28	26.28	131.54	2.33	28.88	12.42	143.96

ANNEXURE-IV-Technical Data

DEAD WEIGHT OF MATERIALS

Items	Weight
Excavated Materials	
Clay (dry)	1600 kg/m ³
Clay (damp, plastic)	1760 kg/m ³
Earth (dry, loose)	1200 kg/m ³
Earth (packed)	1520 kg/m ³
Liquids	
Water	1000 kg/m ³
Building Materials	
Bricks	1600 kg/m ³
Cement	1400 kg/m ³
Steel	7800 kg/m ³
Timber	570-720 kg/m ³
Structural items	
Brick Masonry	1920 kg/m ³
Brick wall, 15 cm thick	295 kg/m ³
Brick wall, 23 cm thick	440 kg/m ³
Cement plaster, 2.5 cm thick	44 kg/m ³
Concrete	2306 kg/m ³

WIND VELOCITY AND PRESSURE AT VARIOUS EXPOSED HEIGHTS

Height of Exposed Surface above Mean Retarding Surface (m)	Horizontal Wind Velocity (km/hr)	Horizontal Pressure (kg/m ²)
0	80	40
3	96	58
6	108	73
9	115	85
12	123	98
15	128	105
18	133	112
21	137	120
24	141	127
27	144	133
30	147	141
38	155	151
46	160	166
53	165	175
61	169	185
76	175	200
92	181	210
107	186	224
122	191	234

ROUND BARS

Diameter in mm	Weight per meter in Kgs	Sectional area Cm ²	Perimeter Cms
6.0	0.22	0.28	1.88
8.0	0.39	0.50	3.51
10.0	0.62	0.79	3.14
12.0	0.89	1.13	3.77
16.0	1.58	2.01	5.03
20.0	2.47	3.54	6.28
25.0	3.85	4.91	7.85

Hazen-William's coefficient

Pipe Material	Recommended C Values	
	New Pipes @	Design purpose
Unlined Metallic Pipes		
Cast iron, Ductile iron	130	100
Mild steel	140	100
Galvanised iron above 50mm dia #	120	100
Galvanised iron 50mm dia and below use for house service connections. #	120	55
Centrifugal Lined Metallic Pipes		
Cast iron, Ductile iron and Mild steel pipes lined with cement mortar or epoxy		
Upto 1200 mm dia	140	140
Above 1200 mm dia	145	145

@ The C values for new pipes include for determining the acceptability of surface finish of new pipelines. The user agency may specify that flow test may be conducted for determining the C values of laid pipelines.

The quality of galvanizing should be in accordance with the relevant standards to ensure resistance to corrosion through out its design life.

*

TREATMENT

Aim

To improve the raw water quality to the drinking water standards and stop water borne transmission of epidemics.

Method of treatment	Depends on the nature of source and its water quality
Sub-surface source	Generally chlorination will be sufficient except where iron is present.
Surface source	Aeration (if required), pre-chlorination (optional), sedimentation – either plain or with coagulation and

AERATION

flocculation, filtration and post chlorination.

Aim

- i) To improve objectionable tests and odours.
- ii) for expulsion of carbon dioxide, hydrogen sulphide.
- iii) to precipitate iron and manganese present in ferrous and manganeous State.
- iv) for increasing the dissolved oxygen content of water.

Types

- i) Spray Type Nozzle dia 10-40 mm
Spacing 0.5 – 1.0 m
Head required 2 – 7 m
Rating of aerator 300-600 lpm per nozzle
Floor area of aerator 360 to 1080 m² per mld
- ii) Multiple tray or water fall
Dia. Of filter media 50-150 mm in various trays
Height of tower 2 m
No. of trays 4 – 9
Spacing of trays 0.30 – 0.75 m
Space required 180 to 540 m² per mld
- iii) Cascade Type
Head required 1 to 3 m
Space required 180 to 540 m² per mld

PRE-CHLORINATION

Aim

- To prevent algae growth in raw water.
- for destruction of some taste odour producing components
- for oxidation of iron, manganese and hydrogen sulphide
- for acid coagulation

Dosage

1 to 5 ppm depending on the degree of pollution so as to leave 0.2 to 0.5 ppm free residual chlorine in the final delivered water.

PLAIN SEDIMENTATION

Aim

To separate suspended impurities from water by gravitation.

Detention Period

One to several days for sedimentation without subsequent filtration :
3 to 4 hours for sedimentation in conjunction with filters. (much longer settling time for basins preceding slow sand filters than for rapid sand filters.)

Loading Rate

30-40 m³/day/m²

CHEMICAL DOSING

Types	Dry feed , Solution feed
Strength of solution	To be $\geq 5\%$ for manual feed And $\leq 10\%$ for mechanical feed. Alum is the most common coagulant used Lime is also added when pH and alkanity are low.
Dosage for alum	20-100 mg/l (1.5 grains/gallon)
Dosage for lime	About one third that of alum
Density of alum	980 kg/m ³
Density of lime	670 kg/m ³

TABLE FOR ALUM REQUIREMENT

Sl. No.	Turbidity	Alum	Capacity of water treatment plant (Thousand litres/day)						
		Dose	1.0	1.50	1.75	2.0	2.5	3.0	4.5
			Alum Requirement (kg./Hr.)						
1	25	5	0.20	0.30	0.35	0.40	0.50	0.60	0.95
2	50	10	0.40	0.60	0.70	0.80	1.00	1.20	1.85
3	100	20	0.80	1.20	1.40	1.65	2.05	2.45	3.70
4	200	25	1.00	1.50	1.80	2.05	2.55	3.10	4.60
5	300	30	1.20	1.85	2.15	2.45	3.10	3.70	5.50
6	400	35	1.40	2.15	2.50	2.85	3.60	4.30	6.45
7	500	40	1.60	2.45	2.85	3.30	4.10	4.90	7.40
8	700	50	2.00	3.10	3.60	4.10	5.10	6.15	9.20
9	1000	55	2.20	3.40	3.95	4.50	5.65	6.75	10.10
10	2000	65	2.70	4.00	4.65	5.35	6.65	8.00	12.00
11	3000	80	3.30	4.90	5.75	6.55	8.20	9.85	14.70

FLASH MIXING

Aim	To disperse the coagulant evenly in the water Generally used when flow exceeds 300 m ³ /hour
Detention period	20-100 mg/l (1-5 grain/gallon)
Head loss	0.20 to 0.60 m of water
Ratio of tank dia to height	1.1 to 3.0
Speed of propeller shaft	100 rpm
Power required	24 to 72 watts/mld

COAGULATION AND FLOCCULATION

Aim: The addition of a coagulant like alum promotes the formation of micro flocs which are the nuclei for the absorption of turbidity and colour causing particles. During flocculation the micro flocs particles formed during rapid mixing are brought together to aggregate into larger rapidly settleable flocs by controlled agitation of water

Detention Period	15-30 minutes in flocculation zone 2-3 hours in settling or clarifier zone	
Dosage	to be decided by jar test	
Flocculator	i)	Ave. velocity of flow 0.3 m/min
	ii)	Paddle area 10-25% of the area swept
	iii)	Max. peripheral velocity 0.6 m/sec
	iv)	Speed 2 rpm
	v)	Allowable head loss 0.15 m
Clarifier	i)	Ave. velocity of flow 0.5 m/sec
	ii)	Max. peripheral velocity 0.5-1.0 cm/sec
	iii)	Tank dimension
	a)	For rectangular tanks Length to width ratio 2 to 4 Depth 2.5 to 4.0 m (and additional 0.15 to 0.30 m if sludge storage is to be provided)
	b)	For circular tanks Dia Not more than 60 m Depth 2.5 to 4.0 m and a space equivalent of 25% of volume for settling for sludge storage.
	iv)	Surface loading For gritty particles of sp. 12-160 m ³ /day/m Gravity 2.65(depending on sizes of the particles 2.0 to 0.5 mm) For amorphous flow 32-80 m ³ /day/m ² Settling solids A surface overflow rate of 36 m ³ /m ² /day is equivalent to a settling

velocity of 1.5 m/hr and amounts to a detention period of 2 hours in basin of 3 m deep.

v)	Weir overflow rate	Not to exceed 600 m ³ /day/m and preferably to held below 300m ³ /day/m
vi)	Sludge removal	Min. size to be used
	For non-mechanised Units	200 mm dia desludging pipe.
	For mechanised units	100mm to 150mm dia desludging pipe
vii)	Bottom slope	
	For manual scraping	1 in 10
	For mechanical scraping	1 in 12
viii)	Allowance head loss	0.50 m
ix)	Power required	0.15-0.20 kw/mld

Note: MLD rating implies 24 hrs.Functioning

FILTRATION

Aim

- To separate the suspended and colloidal impurities in the water.
- To produce sparkling and aesthetically attractive water free from disease producing organisms.

Slow Sand Filters

Influent turbidity	Should not be more than 30 J.T.U.
Pretreatment	Nil. Except plain sedimentation which is required when there is no raw water storage in source.
Length of filter run	not less than 6-8 weeks with loss of head not more than 1.3 m.
Filtration rate	100-150 lph/m ²
Allowable head loss	0.6 to 1.3m ²
Depth of sand	75 – 80 cms thick E.S.O – 0.3 mm U.C. - 2.5
Depth of gravel	20-30 cms in 4 layers graded from 2 to 45 mm.
Depth of water over sand	1.0 to 1.5m
Underdrain system with open joints. in drain	Baked clay or concrete pipes 30-40 cms long at 2m. Spacing laid. The approximate. Spacing underdrains being 3M, velocity of flow pipes 25 cm/sec

Rapid Sand Filters

Influent turbidity	After pretreatment should not exceed 20 J.T.U.
Pretreatment	Required (chemical dosing, flocculation and clarification)
Length of filter run	not less than 24 hours with loss of head not more than 2 m
Filtration rate	80-160 lpm/m ² (240 lpm/m ² can be achieved with improved pretreatment and careful grading)
Head loss allowed	1.8 to 2.0 m

Depth and sand	60-75 cm thick E.S. = 0.45-0.70 mm U.C. = 1.30-1.75 (graded with finest at top)
Depth of gravel:	30-60 cm thick graded into 4 or more sizes varying from 25 to 85 mm at bottom and 2 to 5 mm at top.
Depth of water over sand	1.0-2.0 m
Underdrain system:	Central manifold with laterals with perforations on their bottom or having umbrella types of strainers on top. Other types are wheelers bottom or a porous plate floor supported on concrete pillars.
Minimum depth of Underdrains	20 cm
Dia. Of perforations	5 to 12mm (Staggered at a slight angle from the vertical axis of the pipe)
Spacing of perforations along Laterals	8 cm for a perforation of 5 mm
Ratio of total area of Perforations to total cross Sectional Area of laterals	20 cm for a perforation of 12mm 0.50 for 12mm size and 0.25 for 5 mm size
Ratio of length of lateral to its Dia.	60
Spacing to laterals	30 cm
Cross sectional area of manifold	1.5-2.0 times the total area of laterals
wash water gutter:	Horizontal travel of dirty water over the surface of filter shall not be more than 0.5 to 1.0 m before reaching the gutter. Bottom of gutter should clear the top of expanded sand by 50 mm or more. Upper edge of gutter should be placed as far as above the surface of the undisturbed sand surface as the wash water rises in 1 minute.
Back wash:	Pressure should be such that the sand expands to about 130 to 150% of its undisturbed volume or 5 m head of water as measured on underdrains. Normally the rate at which wash water is applied where no over-agitation is provided is 600 lpm ² of filter surface equivalent to a rise of 60cm per minute in the filter box for a period of 10 minutes. The capacity of wash water storage tank should be sufficient to supply wash water to 2 filter units at a time, where the units are 4 or more to give a normal wash to filters for about 10 minutes at the maximum rate without requiring refilling of tank.
Velocity in filtered water outlet	: not more than 1.0-1.8 m/sec.
Velocity in wash water outlet	: not more than 2.4-3.6 m/sec.

Pressure Filters

Same principle as gravity type rapid sand filters but water is passed through the filters under pressure.

Tank axis may be vertical or horizontal

Disadvantages

- i) pretreatment is not possible without secondary pumping
- ii) Complicates effective feeding, mixing and flocculation
- iii) Adequate contact time for chemicals not possible
- iv) Observance of effectiveness of back wash not possible
- v) Difficult to inspect, clean and replace

Advantages

- i) Secondary pumping is avoided for treated water.
- ii) Filter backwash is complicated
- iii) Suitable for small industries and swimming pools

POST CHLORINATION

Aim: For Disinfection of potable water by the use of gaseous chlorine or chlorine compounds to destroy bacteria through the germicidal effects of chlorine may be done at head works/treatment works and supplemented by additional chlorination in loose pockets of distribution system.

Dosage:

When prechlorination is adopted, relatively small doses will be required, generally 1 to 2 mg/l

Contact period

30 minutes (minimum)

Residual chlorine

0.2-0.8 ppm throughout the distribution system

pH value

6-7 7-8 8-9 9-10 10-11

Residual or free available

0.2 0.2 0.4 0.8 0.8

Chlorine in ppm

Quantity of chemical

Dosage in mg/l x quantity of water to be treated in mld.

required in kg/day

Specific gravity of chlorine

2.49

Density of chlorine

3.214 g/litre

Appropriate Chlorine Doses for Different Purposes

Purpose of Addition		Dose mg/l
1.	Colour removal	5 to 100
2.	Iron bacterial control	2 to 10
3.	Iron precipitation	0.63 times iron content
4.	Manganese precipitation	1.3 times manganese content
5.	Hydrogen sulphide odour removal	2.1 times HS content
6.	Ammonia removal	10 times the ammonia content

BACTERIAL & CYSTICIDAL CONCENTRATIONS OF FREE RESIDUAL CHLORINE

pH value	Free residual chlorine mg/l	
	Bactericidal 0 to 25 ⁰ C	Cysticidal 22 ⁰ to 25 ⁰ C
6.0	0.2	2.0
7.0	0.2	2.5
8.0	0.2	5.0
9.0	0.6	20

TABLE FOR TCL REQUIREMENT

Sr. No.	Chlorine	Capacity of water treatment plant (Thousand litres/day)						
	Mg/l	1.0	1.50	1.75	2.0	2.5	3.0	4.5
		TCL Requirement (kg./Hr.)						
1	2	0.30	0.45	0.55	0.60	0.75	0.90	1.35
2	3	0.40	0.60	0.70	0.80	1.10	1.22	1.80
3	4	0.55	0.85	0.95	1.10	1.45	1.65	2.45
4	5	0.70	1.65	1.25	1.40	1.75	2.10	3.15

Note: 30% chlorine in TCL is assumed.

**TABULAR FORM SHOWING DISCHARGES IN LPM
AGAINST HEAD IN CMS. FOR 60 & 90 DEG. V- NOTCHES.**

SINo.	For 60 deg. V-Notch			For 90 deg. V-Notch		
	Head in cms	Head in Inches	LPM	Head in Inches	Head in cms	LPM
1	0.5	0.20	0.1	0.20	0.5	0.2
2	1	0.39	0.5	0.39	1	0.9
3	1.5	0.59	1.4	0.59	1.5	2.4
4	2	0.79	2.8	0.79	2	4.6
5	2.5	0.98	4.9	0.98	2.5	8.6
6	3	1.18	7.9	1.18	3	13.5
7	3.5	1.38	11.4	1.38	3.5	20
8	4	1.57	15.9	1.57	4	27.7
9	4.5	1.77	21.5	1.77	4.5	37.2
10	5	1.97	27.9	1.97	5	48.4
11	5.5	2.17	35.4	2.17	5.5	61.4
12	6	2.36	40.1	2.36	6	76.3
13	6.5	2.56	53.8	2.56	6.5	93.2
14	7	2.76	64.8	2.76	7	112.2
15	7.5	2.95	77.0	2.95	7.5	133.3
16	8	3.15	90.4	3.15	8	156.6
17	8.5	3.35	105.2	3.35	8.5	182.3
18	9	3.54	121.4	3.54	9	210.3
19	9.5	3.74	139.7	3.74	9.5	241.9
20	10	3.94	158.0	3.94	10	273.6
21	10.5	4.13	178.5	4.13	10.5	309.1
22	11	4.33	200.5	4.33	11	347.3
23	11.5	4.53	224.1	4.53	11.5	388.1
24	12	4.72	249.2	4.72	12	431.7
25	12.5	4.92	276.0	4.92	12.5	478
26	13	5.12	304.4	5.12	13	527.3
27	13.5	5.31	334.7	5.31	13.5	579.8
28	14	5.51	366.4	5.51	14	634.6
29	14.5	5.71	400.0	5.71	14.5	692.8
30	15	5.91	435.3	5.91	15	753.9
31	15.5	6.10	472.5	6.10	15.5	818.5
32	16	6.30	511.6	6.30	16	886.1
33	16.5	6.50	548	6.50	16.5	957
34	17	6.69	595.3	6.69	17	1031
35	17.5	6.89	640.1	6.89	17.5	1109

36	18	7.09	686.7	7.09	18	1190
37	18.5	7.28	735.4	7.28	18.5	1274
38	19	7.48	786.1	7.48	19	1362
39	19.5	7.68	838.9	7.68	19.5	1453
40	20	7.87	893.7	7.87	20	1548

ANNEXURE-V Check Lists for Construction Quality Management at Site

Sl.No.	Elements	Yes / No.
1.	Is coarse aggregate as per Specification	
2.	Is fine aggregate as per Specification	
3.	Is cement fresh & free from clods	
4.	Does the cement set within one hour	
5.	Is sand free from silt	
6.	Are steel bars of correct diameter	
7.	Does the steel bend without breaking	
8.	Are the pipes from tested consignment	
9.	Is the pumping machinery identical to tested sample	
	FOUNDATION	
1.	Are the foundation approved by the engineer including SBC	
2.	Is sand filling provided	
	PLAIN/REINFORCED CONCRETE	
1.	Is Concrete Mixer used	
2.	Is water measured for concreting	
3.	Is vibrator used	
4.	Is slump test done	
5.	Is bulking of sand determined	
	MASONRY	
1.	Are bricks soaked in water before use	
2.	Are joints broken	
3.	Whether Masonry started from corner	
4.	Whether masonry constructed for uniform Height	
5.	Is mortar applied to each brick before placing in position	
6.	Is dressing of stone done before placing	
7.	Is watering of stone done before placing	
8.	Are bond stones dressed	
9.	Is base of face stones more than height	
10.	Is the masonry to plumb	
11.	Are the joints raked	

	RCC WORKS	
1.	Are cover blocks cast in CM 1:2	
2.	Are centering supports spaced less than 0.6 mts and adequate braces provided	
3.	Are the posts resting on firm ground with wooden wedges	
4.	Are steel plates used for centering bottoms and sides	
5.	Are the gaps in centering closed	
6.	Is centering level checked	
7.	Is plumb checked for columns	
8.	Is centering checked/approved before placing reinforcement	
9.	Is reinforcement as per drawings	
10.	Are chairs used to prevent disturbance of reinforcement	
11.	Are lap lengths OK and at suitable position	
Sl.No.	Elements	Yes / No.
12.	Is reinforcement checked/approved and measurement Recorded before placing concrete	
13.	Is waterproofing done when roof slabs are green	
14.	Is curing being done at the time of visit	
15.	Is demoulding done after the required period	
16.	Are patches of surface touched immediately after demoulding	
	PLASTERING	
1.	Is the sand for plastering free from silt	
2.	Is the surface cleaned and watered before plastering	
3.	Are the plumb, line and thickness checked and correct	
	PIPE, SPECIALS AND APPURTENANCE	
1.	Are the locations as per plans	
2.	Are the flanged dimensions as per standard thickness, pitch Circle/dia	
3.	Are the faces of flanges machined	
4.	Is rubber insertion of required quality and thickness	
5.	Are the bolts and nuts are good quality and sizes	
6.	Are the pipes and specials aligned to gradient and plumb	
7.	Are the bolts and nuts tightened properly	
8.	Are the specials and valves supported properly	
9.	Are thrust blocks provided for bends	

	PIPE LAYING	
1.	Is alignment of lines as per plans	
2.	Is trench dimensions and levels as per plans	
3.	Is the soil at the bottom of pipes good for laying of pipes	
4.	Are the pipes and specials lowered and aligned true to gradient and line	
5.	Is the required cushion provided	
6.	Are pipe ends cleaned before joining	
7.	Follow manufacturers instruction for joining (PVC pipes)	
8.	Are the pipes cleaned inside before laying	
9.	Are the ends of pipelines closed before the days work	
10.	Are air valves and reflex valves, scour valves provided at stipulated locations	
11.	are the pipe lines tested before commissioning	
12.	Is refilling done gently and consolidated	

CHECKS TO BE CARRIED OUT IN TRANSMISSION SYSTEM

PROGRAMME FOR CARRYING OUT CHECKS IN THE TRANSMISSION SYSTEM

A programme has to be prepared for each zone of the transmission system which shall contain procedures for routine tasks, checks and inspections at intervals viz. Daily, weekly, quarterly semi-annually or annually. This plan shall fix responsibility, timing for action, ways and means of completing the action as to when and who should take the action and the need to take these actions. Simple checklists for use by the managerial staff can be prepared to ensure that the O & M staff has completed the tasks assigned to them.

CHECK LISTS

S.No.	Checks required/undertaken	Status	Suggested frequency of reporting
1.	Check whether the operation of valves is smooth without any abrupt stoppage during closure		
2.	Check whether closure of valve results in complete stoppage of flow or if any flow passes the valve (passing valve)		
3.	Check for status of scouring and then proper closure of washout valves		
4.	Check for leaks through pipes		
5.	Check for leakage through valves at gland, bolts or any other place		
6.	Check for leaks at the appurtenances including expansion joints		
7.	Check for any signs of corrosion of pipelines		
8.	Check for the status of manhole covers over the chamber covers; are they corroded		
9.	Inspect for any possibilities of pollution of the transmission system		
10.	Check status of out-fall drain for scour valves and chances of contamination at scours		
11.	Assess the need for painting of the exposed piping work		
12.	Check for availability of spares for valves, expansion joints and pipes and jointing materials		
13.	Carry out review of pressures		
14.	Carry out review of flows		
15.	Check age of pipes/C value of pipes		
16.	Check for corrosive water		
17.	Study inflows and outflows into the reservoirs linked to the transmission system		
18.	Identify source of leakage		
19.	Metering		
	Status of bulk metering		
	Review facilities for repair of meters		
20.	Availability of updated system map		

CHECKS TO BE CARRIED OUT AT SRS

A programme has to be prepared for each SR which shall contain procedures for routine tasks, checks and inspections at intervals viz. Daily, weekly, quarterly semi-annually or annually. This plan shall fix responsibility, timing for action, ways and means of completing the action as to when and who should take the action and mention to take these actions. Simple checklists for use by the managerial staff can be prepared to ensure that the O & M staff has completed the tasks assigned to them.

CHECK LISTS FOR CLEAR WATER SUMP AND RESERVOIR

S.No.	Checks required/undertaken	Status	Suggested frequency of reporting
1.	Proper closure of washout valves; any abrupt stoppage during operation.		
2.	Proper closure of inlet valves; any abrupt stoppage during operation.		
3.	Proper closure of outlet valves; any abrupt stoppage during operation.		
4.	Proper closure of bye pass valves; any abrupt stoppage during operation.		
5.	Does any valve pass water even after closure.		
6.	Leaks through valves; glands and bolts and nuts.		
7.	Leaks through pipes and joints at SR.		
8.	Status of valve chambers and their covers.		
9.	Status of finial ventilators; fly proof mesh intact or is to be replaced.		
10.	Status of manhole covers; are they corroded?		
11.	Functioning of water level indicators.		
12.	Functioning of flow meters.		
13.	Status of ladders and railing; are they corroded?		
14.	Check whether quality of the water in the SR is OK.		
15.	Possibility of SR water getting polluted.		
16.	Check for the need for cleaning and disinfecting the SR.		
17.	Check for the presence of residual chlorine in the water stored in SR.		
18.	Check for signs of corrosion of interior of roof due to chlorine.		
19.	Check for structural damages of the SR.		
20.	Check for Leaks through the structure of the SR.		
21.	Status of interconnecting pipe work? Is it corroded?		
22.	Status of lightning arrestor.		
23.	Status of out-fall drains of scour and overflow at SR.		
24.	Availability of :		
	Spares		
	Consumables		
	Tools		
25.	Check for need for painting.		
26.	Check for availability of drawings and designs of the SR.		

* To be decided by the respective water utilities.

CHECKS TO BE CARRIED OUT IN DISTRIBUTION SYSTEM PROGRAMME FOR CARRYING OUT CHECKS

A programme has to be prepared for each zone of the distribution system which shall contain procedures for routine tasks, checks and inspections at intervals viz. Daily, weekly, quarterly semi-annually or annually. This plan shall fix responsibility, timing for action, ways and means of completing the action as to when and who should take the action and mention the need to take these actions. Simple checklists for use by the managerial staff can be prepared to ensure that the O & M staff has completed the tasks assigned to them.

CHECK LISTS

S.No.	Checks required/undertaken	Status	Suggested frequency of reporting
1.	Check whether the operation of valves is smooth without any abrupt stoppage during closure.		
2.	Check whether closure of a valve results in complete stoppage of flow or if any flow passes the valve (passing valve)		
3.	Check for status of scouring and then proper closure of washout valves		
4.	Check for leaks through pipes		
5.	Check for leakage through valves at gland, bolts or any other place		
6.	Check for leaks at the appurtenances		
7.	Check for any signs of corrosion of pipelines		
8.	Check for the status of manhole covers over the chamber; are they corroded		
9.	Inspect for any possibilities of pollution of the distribution system		
10.	status of out-fall drain for scour and overflow		
11.	Assess the need for painting of the piping work		
12.	Check for availability of spares for valves and pipes and jointing materials		
13.	Review the method of giving consumer connections in the field.		
14.	Preparation of water budget for each zone served by one reservoir.		
15.	Number of connections given		
16.	Number of meters out of order		
17.	Status of hydrants and PSPs		
18.	Status of distribution system		
19.	Review of pressures		
20.	Review of flows		
21.	Age of pipes/C value of pipes		
22.	Corrosive water		
23.	Study of inflows and outflows		
24.	Identify source of leakage		
25.	Metering		
26.	Status of bulk metering and consumer		
27.	Review facilities for repair of consumer meters		
28.	Unauthorised connections if any		
29.	Status of fire hydrants and PSPs		
30.	Availability of updated system map		
31.	Need for any interconnections		

ANNEXURE-VI Check Lists for Operation and Maintenance

1. Source & Intakes

- i) Monitoring for inflows
- ii) Monitoring for Drawals
- iii) Monitoring for Evaporation
- iv) Rainfall
- v) Temperature
- vi) Other Meteorological data
- vii) Quality of Raw Water/Algae presence
- viii) Sanitary survey
- ix) Industrial & Domestic Discharge
- x) Animal origin and agricultural run off
- xi) Presence of Algae.
- xii) Action plan for chlorination of raw water
- xiii) Check for variations in the source, for each month
- xiv) Regime tables for filling and emptying of reservoirs

2. Earthen Dams/ Summer storage tanks

- i) Slipping of slopes
- ii) Damages and water seepage
- iii) Functioning of sand galleries
- iv) Functioning of drains
- v) Functioning of relief wells

3 Intakes in Summer Storage Tanks

- i) Water levels
- ii) Operation of gates
- iii) Cleaning of intake strainers
- iv) Schedule of painting of steel and structural works
- v) Desilting of wells

4 Transmission

- i) Check for stock of spare pipes and specials and jointing materials for replacement
- ii) Performance of Sluice valves, air valves, expansion joints, rollers
- iii) Leak detection surveys
- iv) Inspect record of break downs and to identify vulnerable lengths for special attention

5.Treatment Plant

- i) Flow Meter
- ii) Float sump cleaned of silt
- iii) Calibration and checking accuracy
- iv) Servicing
- v) Charts and pen recorders

6. Chemical Feeding Unit

- vi) Painting alum tanks
- vii) Cleaning of V notch weirs and floats
- viii) Spares for mixing unit
- ix) Inspect Jar test facilities

Flash mixer

- x) painting
- xi) Spares for flash mixer

Flocculator

- xii) Painting
- xiii) Lubrication of mechanical devices
- xiv) Non-mechanical - desludging for every six months

Clarifier

- xv) Overhauling
- xvi) Painting prior to monsoon
- xvii) Condition of sludge lines
- xviii) Free movement of telescopic sludge device
- xix) Check for Alignment of wheels-rubber wheels may be replaced
- xx) Outlet weirs (Biological growth - Algae growth)
- xxi) Efficiency of various units
- xxii) Trolley Wheels
- xxiii) Lubricating
- xxiv) Reduction gear box
- xxv) Checking oil
- xxvi) Turn table
- xxvii) Checking oil
- xxviii) Vehicle motors
- xxix) Cleaning of dust
- xxx) Carbon brushes
- xxxi) Bearings
- xxxii) Rail / Track
- xxxiii) Gap between two rails and Alignments
- xxxiv) Rubber wheels - Wear & tear, alignment
- xxxv) MS Scraper & Bolts and nuts
- xxxvi) Squeezers

7. Rapid Gravity Filters

- i) Check for water quality at various stages Daily Check for alum dose
- ii) Check for washing
- iii) Note the readings regarding:
- iv) Quantity of water received
- v) Quantity of water wasted
- vi) Quantity of filtered water produced
- vii) Quantity of water consumed for back
- viii) washing of filters
- ix) Pressure gauge reading at blower
- x) Loss of head for filters just before wash & after wash
- xi) Rate of filtration
- xii) Quality of filtered water
- xiii) Observation for any sand carried away
- xiv) Adequate depth of water over filter media
- xv) Status of operation of valves
- xvi) Performance of blower
- xvii) Uniform washing of bed by air and water
- xviii) (search for dead pockets)
- xix) Check for sand depth & air binding
- xx) Observe length of filter run and loss of head and compare

-
- xxi) Observe rate of filtration
 - xxii) Performance of filter regarding output & quality
 - xxiii) Check the surface of filter media for cracks, encrustation of media, mud balls slime growths
 - xxiv) Check for media depth
 - xxv) Check performance of filters
 - xxvi) Status of functioning of: Instrumentation, Valves, Blowers
 - xxvii) Check for corrosion of all underwater equipment

8. Chlorinators

Note the following readings:

- i) Dosage of chlorine, Residual of chlorine and Pressure readings of chlorine
- ii) Observe for leakage of Gas
- iii) Uninterrupted supply of water for chlorinator
- iv) Functioning of Rotameter
- v) Functioning of rate setter
- vi) Status of Gas filters
- vii) Check for leakage
- viii) Check for signs of corrosion
- ix) Check for spare cylinders
- x) Functioning of Chlorinator panel
- xi) Availability of replacement spares
- xii) Availability of adequate chlorine gas cylinders stock
- xiii) Check the incoming water lines
- xiv) Check the solution feeder lines
- xv) Check the ventilation of chlorine house
- xvi) Check the structural safety of chlorine house

9. Transformers

- i) Oil level in transformer
- ii) Relay alarm circuit
- iii) Load (Amperes)
- iv) Voltage
- v) Bushings
- vi) Dehydrating breathers
- vii) Voltage tap changing switch
- viii) Dielectric strength of oil
- ix) AB switch contacts
- x) Drop in fuse contacts
- xi) All bus bars
- xii) Earth resistance
- xiii) Lightning arresters
- xiv) Relays
- xv) Oil in transformers
- xvi) Once in 2 years
- xvii) Painting to transformers, poles and fencing

10 Motors

Daily checks

- i) Eliminate dirt (Less than 1 000 KVA)
- ii) Anti moisture precautions
- iii) Oiling and greasing to avoid friction
- iv) Check for vibration

-
- v) Check for tightness of contacts
 - vi) Operation at rated voltage
 - vii) Check tripping elements to offer protection
 - viii) Inspect contact points for any deposition
 - ix) Clean the cabinet to remove dirt
 - x) Check for fuse ratings
 - xi) Check whether manufacturers recommendations are followed regarding
 - xii) Quality of oil and grease
 - xiii) Correct periodical of lubrication
 - xiv) (avoid over-lubrication)
 - xv) Check for performance of capacitors

11 Pumps

Daily Checks :

- i) Timing of pump running
- ii) Observe for leakges through stuffing box
- iii) Bearing temperature
- iv) Any undue noise or vibration
- v) Readings of pressure, voltage and current

vi) Half Yearly checks

- vii) Free movement of the gland of stuffing box
- viii) Cleaning and oiling of gland bolts
- ix) Inspection of the gland packing
- x) Alignment of pump and drive
- xi) Cleaning of oil lubricated bearings/or grease lubricated and replacing oil and grease
- xii) Clean and examine all bearings for flows

xiii) Annual Checks :

- xiv) Examine shaft sleeves for wear or scour
- xv) Check clearance at wearing ring
- xvi) Check impeller hubs and vane tips for pitting or erosion
- xvii) Calibration of all instruments and flow meters
- xviii) Check performance of pump Q, H, KW and efficiency
- xix) Check for availability of required tools
- xx) Check for availability of lubricants and other consumables such as gland packing, bolts etc.
- xxi) Check for repair facilities such as pullers, clamps, machinery, welding set, grinder,
- xxii) blower, drilling machine etc.
- xxiii) Records to be kept on the Operations :
- xxiv) Note the water levels in the SR s (for all compartments) at hourly intervals.
- xxv) Note the time and relevant operation of control valves with time of opening and closure or throttling position of the valves.
- xxvi) Note the hourly flow meter readings both on the inlets and outlets
- xxvii) Note the hourly residual chlorine readings of inflow water and outflow water
- xxviii) Record on when the structure of the reservoir was last repaired to attend to structural defects or arrest leakage and the cost of materials and labour cost thereof
- xxix) Record on when the reservoir was last cleaned and the cost of materials and labour cost thereof
- xxx) Record on when the reservoir was last painted and the cost of materials and labour cost thereof
- xxxi) Record on when the piping at the reservoir was last painted and the cost of materials and labour cost thereof

12 Clear Water Sump and Service Reservoir (SR)

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-
- i) Check for proper closure of washout valves
 - ii) Check for functioning of Water level indicators
 - iii) Check for status of ventilators; whether Fly proof mesh over ventilators requires to be replaced
 - iv) Check for the status of Manhole covers; are they corroded ?
 - v) Check the water quality and find the necessity to clean and disinfect insides
 - vi) Check whether the roof of SR is clean and whether the surroundings of SR are clean
 - vii) Check whether the Operation of valves is smooth without any abrupt stoppage during closure
 - viii) Check for leakage through valves at gland, bolts or any other place
 - ix) Check whether closure of a valve results in complete stoppage of flow or if any flow passes the valve (passing valve)
 - x) Check for any structural damages to the reservoir especially whether the roof is corroded due to chlorination and assess the structural soundness of the reservoir
 - xi) Assess the status of ladder and railings whether corroded ?
 - xii) Check for leakage through the structure of the SR
 - xiii) Check for leakage through interconnecting pipe work at the SR
 - xiv) Check for any signs of corrosion of interconnecting pipe work at the SR
 - xv) Inspect for any possibilities of pollution of the water stored in the reservoir
 - xvi) Status of out-fall drain for scour and overflow
 - xvii) Assess the need for painting of the reservoir and piping work
 - xviii) Assess the status of lightning arrestor where provided
 - xix) Check for the availability of consumables , spares and tools

13 Checks to be carried out in the distribution system :

- i) Check whether the Operation of valves is smooth without any abrupt stoppage during closure
- ii) Check whether closure of a valve results in complete stoppage of flow or if any flow passes the valve (passing valve)
- iii) Check for status of scouring and then proper closure of washout valves
- iv) Check for leaks through pipes
- v) Check for leakage through valves at gland, bolts or any other place
- vi) Check for leaks at the appurtenances
- vii) Check for any signs of corrosion of pipelines
- viii) Check for the status of Manhole covers over the chambers; are they corroded ?
- ix) Inspect for any possibilities of pollution of the distribution system water stored
- x) Status of out-fall drain for scour and overflow
- xi) Assess the need for painting of the piping work
- xii) Check for availability of spares for valves and pipes and jointing materials
- xiii) Review the method of giving consumer connections in the field
- xiv) Preparation of water budget for each zone
- xv) served by one reservoir
- xvi) Number of connections given
- xvii) Number of meters out of order
- xviii) Status of hydrants and PSPs
- xix) Status of Distribution System
- xx) Review of pressures
- xxi) Review of flows
- xxii) Corrosive water
- xxiii) Study of inflows and outflows
- xxiv) Identify source of leakage
- xxv) Status of bulk metering and consumer Metering

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- xxvi) Unauthorised connections if any
 - xxvii) Review facilities for repair of consumer meters
 - xxviii) Status of PSPs
 - xxix) Availability of updated system map

ANNEXURE-VII-Applicable codes

Various Indian standard codes applicable to water supply and sanitation related activity are given in this section.

Sl.No.	IS Code No.	Title
General		
1	SP 7 (Part 9 section 1) : 1983	National building code of Indian 1983 part 9 plumbing services : section 1 : water supply
2.	SP 35: 1987	Hand book on water supply and drainage with special emphasis on plumbing
3.	1172: 1983	Code of basic requirements for water supply drainage and sanitation (third revision)
4.	456: 1978	Code of practice for plain and reinforced concrete (second revision)
5.	457: 1957	Code of general construction of plain and reinforced concrete for dams and other massive structures
6.	1343:1980	Code of practice for pre-stressed concrete (first revision)
7.	6518:1972	Code of practice for control of sediment in reservoirs
8.	7357:1974	Code of practice for structural design of surge tanks
9.	4926:1976	Ready-mixed concrete (first revision)
10	5477	Methods for fixing the capabilities of reservoirs
a	Part 1 : 1969	General requirements
b	Part 2 : 1969	Dead storage
c	Part 3 : 1969	Live storage
d	Part 4 : 1971	Flood storage
11	10221:1982	Code of practice for coating and wrapping of underground steel pipelines
Pipe and Pipe laying		
Cast iron		
12	1537:1976	Vertically cast iron pressure pipes for water, gas and sewage (first revision)
13	1538 (part 1 to 24)	Cast iron fittings for pressure pipes for water, gas and sewage (second revision)
14	1879 : 1965. Pipe Part 1 to 10	Malleable cast iron pipe fittings (first revision)
15	3114:1985	Code of practice for laying of cast iron pipes (third revision)
16	782:1978	Caulking lead (third revision)
17	616:1978	Centrifugally cast (spun) iron low pressure pipes for water, gas and sewage (first revision)
18	7181:1986	Horizontally cast iron double flanged pipes for water, gas and sewage (first revision)
19	8329:1977	Centrifugally cast (spun) ductile iron pressure pipes for water, gas and sewage
20	9523:1980	Ductile iron fittings for pressure pipes for water, gas and sewage
21	11606:1966	Methods of sampling cast iron pipes and fittings

Sl.No.	IS Code No.	Title
22	11906:1986	Recommendations for cement mortar lining cast iron, mild steel and ductile iron pipes and fittings for transportation of water

23	12288:1987	Code of practice for laying of ductile iron pipes
Concrete		
24	458:1971	Concrete pipes (with and without reinforcement) (second revision)
25	784:1978	Pre-stressed concrete pipes (including fittings) (first revision)
26	1916:1963	Steel cylinder reinforced concrete pipes
27	3597:1985	Methods of test for concrete pipes (first revision)
28	3597:1985	Code of practice for laying of concrete pipes (first revision)
29	4350:1967	Concrete porous pipes for under drainage
Asbestos cement pipes		
30	1592:1980	Asbestos cement pressure pipes (second revision)
31	6530:1972	Code of practice for laying of asbestos cement pressure pipes
32	5531:1977	Cast iron specials for asbestos cement pressure pipes for water, gas and sewage (first revision)
33	9627 : 1980	Asbestos cement pressure pipes (light duty)
Mild steel tubes and pipes		
34	1239	Mild steel tubes, tubulars and other wrought steel fittings.
a	Part 1 : 1979	Mild steel tubes (fourth revision)
b	Part 2 : 1982	Mild steel tubulars and other wrought steel pipe fittings (third revision)
35	1978:1982	Line pipe
36	3589:1981	Electrically welded steel pipes for water, gas and sewage (150 to 2000 mm nominal size) (first revision)
37	5822:1986	Code of practice for laying of welded steel pipes for water supply (first revision)
38	4711:1974	Method for sampling of steel pipes, tubes and fittings (first revision)
39	4736:1986	Hot dip zinc coatings on mild steel tubes (first revision)
Plastic pipes		
40	3976:1985	Low density polyethylene pipes for potable water supplies (second revision)
41	4984:1987	High density polyethylene pipes for potable water supplies, sewage and industrial effluents (third revision)
42	4985:1988	Unplasticized PVC pipes for potable water supplies (second revision)
43	7634	Code of practice for plastic pipe works for potable water supplies
a	Part 1 : 1975	Choice of materials and general recommendation
Sl.No.	IS Code No.	Title
b	Part 2 : 1975	Laying and jointing polyethylene (PE) pipes
c	Part 3 : 1975	Laying and jointing unplasticized PVC pipes
44	7834(Part 1 to) 1975	Injection moulded PVC fittings with solvent cement joints for water supplies
45	8008(Part 1 to7) 1975	Injection moulded HDPE fittings for potable water supplies
a	Part 1 : 1977	General requirements
b	Part 2 : 1977	Specific requirements for 90 ⁰ tees
c	Part 3 : 1977	Specific requirements for 90 ⁰ bends
46	10124(part 1 to	Fabricated PVC fittings for potable water

	13)1988	
47	12231:1988	UPVC pipes for use in suction and delivery lines of agriculture pumps
48	12235(Part 1 to 11)1986	Methods for test for unplasticized PVC pipes for potable water supplies
49	12709 : 1989	Specification for glass fibre reinforced plastic (GRP) pipes for water supply and sewerage
Miscellaneous Pipes		
50	11906 : 1986	Recommendations for cement – mortar lining for cast iron, mild steel and ductile – iron pipes and fittings for transportation of water
Water Meters		
51	779:1978	Water meter (domestic type) (first revision)
52	2104:1981	Water meter boxes (domestic type) (first revision)
53	2373:1981	Water meter (bulk type) (third revision)
54	2401:1973	Code of practice for selection, installation and maintenance of domestic water meters (first revision)
55	6784 : 1984	Method for performance testing of water meters (domestic type) (first revision)
Valves		
56	780:1984	Sluice valves for water works purposes (50 to 300 mm size) (sixth revision)
57	2906:1984	Sluice valves for water works purposes (350 to 1200 mm size) (third revision)
58	2685:1971	Code of practice for selection, installation and maintenance of sluice valves (first revision)
59	3042:1965	Single faced sluice gates (200 to 1200 mm size)
60	3950:1979	Surface boxes for sluice valves (first revision)
61	778:1984	Copper alloy gate, globe and check valves for water works purposes (fourth revision)
62	1701:1960	Mixing valves for ablutionary and domestic purposes
63	1703:1977	Ball valves (horizontal plunger type) including floats for water supply purposes (second revision)
64	4838:986	Foot valves for water works purposes (second revision)
65	5312	Switng check type reflux (non-return) valve for water works purposes

Sl.No.	IS Code No.	Title
	5312 (Part 1) 1984	single door pattern (first revision)
	5312 (Part 2) 1986	Multi door pattern
66	9338:1984	Cast iron screw down stop valves and stop and check valves of water works purposes (first revision)
67	9739:1981	Pressure reducing valves for domestic water supply systems
68	12234:1988	Equilibrium plastic float valve for cold water services
	Miscellaneous Fittings	
69	2692:1978	Ferrules for water services (first revision)
70	10446:1983	Glossary of terms relating to water supply and sanitation
Pumps and related standards		
71	IS 8035:1976	Shallow well hand pumps
72	IS 9301:1984	Deep well hand pumps (second revision)
73	IS 11004:1985	Code of practice for installation and maintenance of deep well hand pumps
a	Part 1	Installation
b	Part 2	Maintenance
Other pumps		
74	IS 1520:1980	Horizontal centrifugal pumps for clear, cold, fresh water (second revision)
75	IS 1710:1972	Vertical turbine pumps for clear, cold, fresh water (first revision)
76	IS 6595:1980	Horizontal centrifugal pumps for clear, cold, fresh water for agricultural purposes (first revision)
77	IS 8034:1976	Submersible pump sets for clear, cold, fresh water
78	IS 8418:1977	Horizontal centrifugal self priming pumps
79	IS 8472:1977	Regenerative self priming pumps for clear, cold fresh water
80	IS 9079:1979	Monoset pumps for clear, cold fresh water for agricultural purposes
81	IS 9137:1978	Code for acceptance test for centrifugal mixed flow and axial pumps – Class C
82	IS 9542:1980	Horizontal centrifugal monoset pumps for cold, fresh water
83	IS 9694	Code of practice for selection, installation, operation and maintenance for horizontal centrifugal pumps for agricultural applications
a	Part 1 : 1980	Selection
b	Part 2 : 1980	Installation
c	Part 3 : 1980	Operation
d	Part 4 : 1980	Maintenance
84	IS 10572:1983	Methods of sampling pumps
85	IS 10981:1983	Code of acceptance test for centrifugal mixed flow and axial pumps – Class B
86	IS 11346:1985	Testing set up for agricultural pumps

Sl.No.	IS Code No.	Title
87	IS 12225:1987	Technical requirements for jet, centrifugal pump combination
88	IS 5120 :1977	Technical requirements for rotodynamic special purpose pumps
Prime Movers		
89	IS 325:1979	Three phase induction motors
90	IS 900:1965	Code of practice for installation and maintenance of induction motors
91	IS 996:1979	Single phase small A.C. and universal electric motors (second revision)
92	IS 4029:1967	Guide for testing three phase induction motors
93	IS 7538:1975	Three phase squirrel cage induction motors for centrifugal pumps for agricultural application
94	IS 8789:1978	Valves of performance characteristics for three phase induction motors
95	IS 9283:1979	Motors for submersible pumpsets
Water Quality		
96	IS 258:1967	Potash alum (first revision)
97	IS 259:1969	Aluminium alum (first revision)
98	IS 260:1969	Aluminium sulphate
99	IS 299:1980	Aluminium ferric (third revision)
100	IS 646:1986	Liquid chlorine (second revision)
101	IS 1065:1971	Bleaching powder, stable
102	IS 1622:1981	Methods of sampling and microbiological examination of water (first revision)
103	IS 3025(Part 1 to 36) 1988	Methods of sampling test (physical and chemical) for water and waste water.
104	IS 9825:1981	Chlorine tablets
105	IS 10500:1983	Drinking
106	IS 10553	Requirements for chlorination equipment
	Part 1:1983	General guidelines for chlorination plants including handling, storage and safety of chlorine cylinders and drums
	Part 2:1983	Vacuum feed type chlorinators
	Part 3:1983	Gravity feed type gaseous chlorinators
	Part 4:1987	Bleaching powder solution feeder displacement type chlorinator
107	IS 3918:1966	Code of practice for use of current meter (cup type) for water flow measurement
108	IS 4080:1967	Specification for vertical staff gauges
109	IS 6062:1971	Method of measurement of flow of water in open channels using standing wave flume – fall
110	IS 6063:1971	Method of measurement of flow of water in open channels using standing wave flume
111	IS 6064:1971	Specification for sounding and suspension equipment
112	IS 9117:1979	Recommendation for liquid flow measurement in open channels by weirs and flumes
113	IS 9922:1981	Guide for selection of method for measuring flow in open channels

ANNEXURE-VIII EPANET 2.0

'EPANET 2.0' is freely available software by 'U.S. Environmental Protection Agency' that models the Hydraulic and Water Quality Behavior of Water Distribution Piping Systems.

EPANET 2.0 is Graphical User Interface (GUI) software and is windows based where as LOOP4.0 is DOS based Software. Hence, EAPANET 2.0 is considered as more user friendly.

Description

Developed by EPA's Water Supply and Water Resources Division, EPANET is software that models water distribution piping systems. It is a Windows 95/98/NT/XP program that performs extended-period simulation of the hydraulic and water quality behavior within pressurized pipe networks.

Pipe networks consist of pipes, nodes (pipe junctions), pumps, valves, and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of the water in each tank, and the concentration of a chemical species throughout the network during a simulation period. Chemical species, water age, source, and tracing can be simulated.

EPANET provides an integrated computer environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.

EPANET is public domain software that may be freely copied and distributed.

Capabilities

EPANET provides a fully equipped, extended-period hydraulic analysis package that can:

- Handle systems of any size
- Compute friction head loss using the Hazen-Williams, the Darcy Weisbach, or the Chezy-Manning head loss formula
- Include minor head losses for bends, fittings, etc.
- Model constant or variable speed pumps
- Compute pumping energy and cost
- Model various types of valves, including shutoff, check, pressure regulating, and flow control
- Allow storage tanks to have any shape (i.e., surface area can vary with height)
- Consider multiple demand categories at nodes, each with its own pattern of time variation
- Model pressure-dependent flow issuing from emitters (sprinkler heads)
- Base system operation on simple tank level or timer controls as well as on complex rule-based controls

In addition, EPANET's water quality analyzer can:

- Model the movement of a non-reactive tracer material through the network over time
- Model the movement and fate of a reactive material as it grows (e.g., a disinfection by-product) or decays (e.g., chlorine residual) over time
- Model the age of water throughout a network
- Track the percent of flow from a given node reaching all other nodes over time
- Model reactions both in the bulk flow and at the pipe wall
- Allow growth or decay reactions to proceed up to a limiting concentration
- Employ global reaction rate coefficients that can be modified on a pipe-by-pipe basis
- Allow for time-varying concentration or mass inputs at any location in the network
- Model storage tanks as being complete mix, plug flow, or two-compartment reactors

EPANET's Windows user interface provides a visual network editor that simplifies the process of building piping network models and editing their properties. Various data reporting and visualization tools are used to assist in interpreting the results of a network analysis. These include graphical views (e.g., time series plots, profile plots, and contour plots), tabular views, and special reports (e.g., energy usage, reaction, and calibration).

Applications

EPANET was developed to help water utilities maintain and improve the quality of water delivered to consumers through distribution systems. It can be used to design sampling programs, study disinfectant loss and by-product formation, and conduct consumer exposure assessments. It can assist in evaluating alternative strategies for improving water quality, such as altering source use within multi-source systems, modifying pumping and tank filling/emptying schedules to reduce water age, using booster disinfection stations at key locations to maintain target residuals, and planning cost-effective programs of targeted pipe cleaning and replacement.

EPANET can also be used to plan and improve a system's hydraulic performance. The software can assist with pipe, pump, and valve placement and sizing; energy minimization; fire flow analysis; vulnerability studies; and operator training.

Programmer's Toolkit

The EPANET Programmer's Toolkit is a dynamic link library (DLL) of functions that allow developers to customize EPANET's computational engine according to their own needs. The functions can be incorporated into 32-bit Windows applications written in C/C++, Delphi, Pascal, Visual Basic, or any other language that can call functions within a Windows DLL. There are over 50 functions that can be used to open a network description file, read and modify various network design and operating parameters, run multiple extended-period simulations accessing results as they are generated or saving them to file, and write selected results to a file in a user-specified format.

The toolkit is useful for developing specialized applications, such as optimization or automated calibration models that require running many network analyses. It can simplify adding analysis capabilities to integrated network-modeling environments based on computer-aided design (CAD), geographical information system (GIS), and database packages.

A Windows Help file is available to explain how to use the various toolkit functions; it offers some simple programming examples. The toolkit also includes several different header files, function definition files, and .lib files that simplify the task of interfacing it with C/C++, Delphi, Pascal, and Visual Basic code.

Multi-Species Extension

EPANET-MSX (Multi-Species eXtension) is an extension to EPANET that enables it to model complex reaction schemes between multiple chemical and biological species in both the bulk flow and at the pipe wall. This capability has been incorporated into both a stand-alone executable program as well as a toolkit library of functions that programmers can use to build customized applications.

The multi-species extension requires a new MSX input file in which the user specifies the mathematical expressions that govern the reaction dynamics of the system being studied. This approach allows users the flexibility to model a wide range of chemical reactions of interest to water utilities, consultants, and researchers. Examples include the auto-decomposition of chloramines to ammonia, the formation of disinfection by-products, biological re-growth including nitrification dynamics, combined reaction rate constants in multi-source systems, and mass transfer limited oxidation-pipe wall adsorption reactions.

EPANET-MSX is distributed in a compressed zip file that contains a command line executable, several libraries of functions, and a User's Manual. The executable can be used to run water quality analyses without any additional programming effort. The function library can be used in conjunction with the existing EPANET Programmer's Toolkit to develop customized applications. At this point in time, the software has not been integrated into a Windows interface, but this may happen at some point in the future.

ABBREVIATIONS

Atm	Atmosphere	Emf	Electromotive force
BOD	Biochemical oxygen demand	Eq	Equation
Ci	Curie	Fig	Figure
⁰ C	Degree centigrade	G	Gram
Cal	Calorie	Ha	Hectare
CC	Cubic centimeter	I.D.	Internal diameter
CCE	Carbon-chloroform extract	JTU	Jackson turbidity unit
cgs	Centimeter gram second	K cal/kg	Kilocalorie per kilogram
CI	Cast iron	Kg/cm ²	Kilogram per square centimeter
cm	Centimeter	KL	Kilolitres
cm/min	Centimeters per minute	KLd	Kilolitres per day
Col	Column	Kwh	Kilowatt hour
Cum	Cubic meters	L	Liter
Cumec	Cubic meter per second	Lpcd	Liter per captia per day
Deg	Degree	Lpd	Liters per day
DO	Dissolved oxygen	Lph	Liter per hour
EDTA	Ethylene diametetraacetic acid	Lph/m ²	Liters per hour per square meter
Lpm/ m ²	Liters per minute per square meter	Lpm	Liter per minute
M	Meter	U	Micron
M3	Cubic meter	MCI	Microcurie
M ³ /hr	Cubic meter per hour	Mgr	Microgram
Me	Milli equivalent	N	Newton
Mg	Milligram	NPSH	Net positive suction head
Mg/l	Milligram per liter	No	Number
ml	Milliliter	NTU	Naphelometric turbidity units
ML	Millon liters	OTA	Orthotolidine arsenite
MLd or mld	Million liters per day	Na	Reynold's Number
Mm	Milimter	P	Page
Mps.or m/s	Meter per second	PP	Pages
Min	Minute	Pci	Picocurie
Mole	Gram molecular weight	Ppb	Part per billioin
MPN	Most probable number	Wt	Weight
M	Millimicron		

Conversion table

LENGTH					
1 In	=	25.4 mm	1 mm	=	0.0394 in
1 ft	=	0.3048 m	1 cm	=	0.3934 in
				=	0.0328 ft
1 yd	=	0.9144 m	1 mm	=	3.2808 ft
				=	1.0936 yd
1 mile	=	1.6093 km	1 km	=	0.6214 mile

AREA					
1 sq in	=	645.163 sq.mm	1 sq.mm	=	0.00155 sq.in
		6.4156 sq. cm	1 sq. cm	=	0.1550 sq. in
1 sq ft		0.0929 sq.m		=	0.00108 sq.ft
1 sq yd	=	0.8361 sq.m	1 sqm	=	10.7639 sq.ft
1 sq. mile	=	2.59 sq. km		=	1.1960 sq. yd
1 acre	=	0.4047 ha	1 ha	=	2.4710 acre
		4046.86 sq m		=	0.00386 sq mile
			1 sq km	=	0.3861 sq. mile
				=	247.105 acre

CAPACITY					
1 gal (UK)	=	4.546091	11	=	0.0353147 cu ft
	=	0.0045609		=	0.001308 cu yd
	=	0.160544 cu ft	11	=	0.2200 gal UK
1 gal (US)	=	0.00378541 cu m	11	=	0.264172 gal US
	=	3.785331			
	=	0.832675 UK gal			
	=	0.133681 cu ft			
1 US pint	=				
(Liquid)	=	0.47321			
1 fluid oz (US)	=	29.5729 ml			
1 fluid oz (UK)	=	28.4123 ml			

VOLUME					
1 cu in	=	16.8871 cu m	1 cu cm	=	0.061024 cu in
1 cu ft	=	0.0283 cu m	1 cu cm	=	35.815 cu ft
1 cu yd	=	0.7646 cu m		=	1.60795 cu yd
1 acre ft	=	1233.48 cu m		=	0.00018071 acre ft
WEIGHT					
1 grain	=	0.0648 g	1 g	=	15.45254 grains
1 oz	=	28.3495 g		=	0.0352740 oz
1 lb	=	0.4536 kg	1 kg	=	2.20462 lb
1 ton	=	1.01605 tonnes	1 tonne	=	0.98421 ton