ENGINEERING STANDARD

FOR

WATER RESOURCES AND DISTRIBUTION SYSTEMS

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1. SCOPE

This Engineering Standard prescribes the water resources and provides recommendations for preliminary planning and engineering of central water supply systems (intake facilities plus distribution network) serving the potable and non-potable water needs of a community. Moreover it sets out the quality requirements of potable and non-potable (irrigation) water and design criteria for designing and sizing of water intake facilities, distribution systems, service reservoirs (including high level tanks) and pumping stations for residential areas in methods that are technically and economically viable and acceptable.

2. REFERENCES

In this Standard the following standards that are referred to, and to the extent specified, form a part of this Standard:

DIN (DEUTSCHES INSTITUT FÜR NORMUNG e.v.)

DIN 2000 Nov. 1973	"Central Drinking Water Supply"
DIN 2001 Feb. 1983	"Private and Individual Drinking Water Supply"
DIN 2425 Oct. 1983	"Plans for Public Supplies, Water Engineering and Long Distance Pipe Lines"

IPS (IRANIAN PETROLEUM STANDARDS)

E-TP-760	"Corrosion Consideration in Design"
E-TP-350	"Linings"
E-TP-270	"Coatings"
C-TP-820	"Electrochemical Protection (Cathodic & Anodic)"
C-TP-742	"Corrosion Consideration During Fabrication and Installation"
C-TP-274	"Coating"
C-TP-352	"Lining"

3. DEFINITIONS AND TERMINOLOGY

3.1 Ghanat

Man made (dug) underground tunnel with moderate slope that collects the percolated groundwater of a catchment area and with gradual decrease of its depth comes out to the surface of earth as a spring at an appropriate point for potable and or non-potable use of mankind. The tunnel is dug through vertical wells approximately 100 meters apart, as required, that act also as venting shafts for periodic inspection and maintenance of the "Ghanat".

3.2 Contaminant

Any physical, chemical, biological, or radiological substance or matter in water.

3.3 Maximum Contaminant Level (MCL)

The maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system.

3.4 Distillation

A process of evaporation and condensation used for the preparation of water of high purity.

3.5 Turbidity

Reduction of transparency of a liquid caused by the presence of undisolved matter.

3.6 Drawdown

Drawdown at any instant is the difference between the static water level and the pumping water level. Drawdown affects the yield of well.

3.7 Well Yield

The volume of water discharged from a well per unit time. It is commonly expressed in litres per second or per minute, or cubic metres per minute, hour or day.

4. UNITS

This Standard is based on International System of Units (SI), except where otherwise is specified.

5. WATER RESOURCES

The source of water commonly determines the nature of the collection, purification, transmission, and distribution works. Common sources of fresh water and their development are:

Surface water, groundwater and seawater (desalinated or distilled).

6. QUALITY OF WATER

Water is the most vital of all life-sustaining substances and is irreplaceable. All of the waters found in nature have some impurities. The raindrops, as they fall, absorb dust, dissolve some oxygen, carbon dioxide and other gasses. At the ground, they take up silt and other inorganic matter. Surface water retains all these impurities for an indefinite period, but that part of the rainfall which percolates into the soil will lose the suspended silt and bacteria through natural filtration.

The total dissolved solids is the numerical sum of all dissolved solids determined by chemical tests. In general, the total concentration of dissolved salts (TDS) is an indication of the overall suitability of water. The quality of water for drinking and irrigation diminishes as the value of TDS increases.

6.1 Quality Standard for Drinking Water

Water intended for human consumption must be free from organisms and hazardous concentrations of chemical substances. The situation, construction, operation and supervision of a water supply system, including its storage and distribution, must be such as to exclude any possible pollution of the water. The standards for drinking water prescribed by the World Health Organization (1971) is the most accepted international standard on the potability of water. In addition, many countries have established national standards for drinking water supplies. Table 1 presents the substances and characteristics affecting the acceptability of water for domestic use.

The "Environmental Protection Agency of Iran" has set a standard for the acceptable quality of drinking water. The said agency has also issued mandatory standard for effluent of wastewaters which is referred to in clause 6.1 of IPS-E-CE-400. The standard issued by "E.P Agency of Iran" for potable water should be considered as mandatory and may replace the WHO (1971) standards referred to in Tables 1 and 2.

TABLE 1 - SUBSTANCES AND CHARACTERISTICS INFLUENCING THE ACCEPTABILITY OF WATER FOR DOMESTIC USE

SUBSTANCE CHARACTERISTICS	UNDESIRABLE EFFECT PRODUCED	HIGHEST DESIRABLE LEVEL	MAXIMUM PERMISSIBLE LEVEL
SUBSTANCES CAUSING DISCOLOURATION	DISCOLORATION	5 UNITS[1]	50 UNITS[1]
SUBSTANCES CAUSING ODORS	ODORS	UNOBJECTIONABLE	UNOBJECTIONABLE
SUBSTANCES CAUSING TASTES	TASTES	UNOBJECTIONABLE	UNOBJECTIONABLE
SUSPENDED MATTER	TURBIDITY	5 UNITS[b]	25 UNITS[b]
TOTAL SOLIDS	TASTE	500 mg/1	1500 mg/1
pH RANGE	TASTE	7.0 TO 8.5	6.5 TO 9.2
ANIONIC DETERGENTS	TASTE AND FOAMING	0.2 mg/1	1.0 mg/1
MINERAL OIL	TASTE AND ODOR AFTER CHLORINATION	0.01 mg/1	0.30 mg/1
PHENOLIC COMPOUNDS (AS PHENOL)	TASTE, PARTICULARLY IN CHLORINATED WATER	0.001 mg/1	0.002 mg/1
TOTAL HARDNESS	EXCESSIVE SCALE FORMATION	2 m Eq/1 (100 mg/1 $CaCO_3$)	10 m Eq/1 (500 mg/1 $CaCO_3$)
CALCIUM (AS Ca)	EXCESSIVE SCALE FORMATION	75 mg/1	225 mg/1
CHLORIDE (AS Cl)	TASTE; CORROSION IN HOT-WATER SYSTEMS	200 mg/1	600 mg/1

[l]Platinum Cobalt Standard
[b]Turbidity Standard

Source: International Standard for Drinking Water, WHO (1971)

6.1.1 Bacterial pollution

The greatest danger to drinking water is that it may have been contaminated by sewage, human excrement or animal pollution. Drinking of such water infected by living pathogens of deseases such as dysentery may result in epidemics.

The organisms most commonly used as indicators of pollution are E. coli and the coliform group as whole. Both are considered to be of faecal origin. Water circulating in the distribution system, whether treated or not should not contain any organism that may be of faecal origin. Frequent bacteriological examinations are essential for hygienic control, (see Note under Table 1). When repairs or extensions to water supply installations are carried out, it is essential that a bacteriological examination of the water should be performed, after the part of the system concerned has been disinfected and before it is put into service. Efficient treatment, usually through chlorination, yields water free from any coliform organisms, however polluted the original raw water may have been.

6.1.2 Chemical substances

A number of chemical substances, if present in certain concentrations in supplies of drinking water, may constitute a health hazard. Table 2 presents the limits of toxic substances in drinking water, as prescribed tentatively by the World Health Organization, assuming an average daily intake of 2.5 liters of water by a man weighing 70 kg.

TABLE 2 - TENTATIVE LIMITS FOR TOXIC SUBSTANCES IN DRINKING WATER

SUBSTANCE	UPPER LIMIT OF CONCENTRATION
ARSENIC (as As)	0.05mg/lit
CADMIUM (as Cd)	0.01mg/lit
CYNANIDE (as Cn)	0.05mg/lit
LEAD (as Pb)	0.1mg/lit
MERCURY (as Hg)	0.001mg/lit
SELENIUM (as Se)	0.01mg/lit

Source: International Standards for Drinking Water, World Health Organization, Geneva (1971).

Note:

For more information on the number of tests required to be carried out for chemical substances, radiological examinations and the coliform test results required to meet the maximum contaminant levels (MCL) for bacteriological quality of drinking water refer to IPS-E-CE-350 (Water Treatment).

6.2 Quality Standard for Irrigation Water

Water acquired from any one of the water resources (clause 5), if used in farmlands no limit of turbidity is set. It is enough to prevent entry of waste waters contaminated with oil and other chemicals harmful to plants into the irrigation water supply system. But if irrigation water be supplied in a separate pipe distribution system (other than drinking water networks) for the needs of irrigation, court-yard washing etc. of residential houses, the recommended maximum turbidity level of such irrigation water is around 20-25 ppm. This limit is attainable with plain sedimentation.

7. WATER RESOURCE SELECTION AND PROTECTION

The water-supply should be obtained from the most desirable source feasible, and effort should be made to prevent or control pollution of the source. If the source is not adequately protected against pollution by natural means, the supply shall be adequately protected by treatment. Sanitary surveys shall be made of the water-supply system, from the source of supply to the connection of the customer’s service piping to locate any health hazards that might exist.

8. WATERWORKS SYSTEM

A waterworks system is designed and executed either as a new project or expansion of an existing system to supply sufficient volume of water at required quality and at adequate pressure from the supply source to consumer points for domestic, irrigation, industrial, fire-fighting and sanitary purposes. Hence, the design of waterworks system needs adequately sized components. The water-supply facilities consist of water intake facilities and water treatment facilities dependent on the need with regard to quality requirements, storage, transmission, pumping, distribution etc.

8.1 Intakes

Water intakes consist of the opening, strainer or grating through which the water enters into a conduit conveying the water, usually by gravity, to a sump or is pumped onshore to presedimentation channels or to mains for direct use or treatment plants as required.

In designing and locating intakes, the following aspects must be considered:

a) The source of supply and the fluctuation of water level or water table.

b) The navigation requirements, if any, and the scouring possibilities of river or lake bottom.

c) The location with respect to sources of pollution.

d) In order to minimize the possibility of interference with the supply, the intakes should be duplicated, wherever possible.

e) Permission should be obtained from the concerned official authorities.

8.1.1 Intakes from impounding reservoirs and lakes

As the water of impounding reservoir varies in quality at different levels it is recommended to take water from about one (1) meter below the lowest water surface. As the water level in reservoirs is expected to fluctuate, gates at various heights should be provided.

In case of lake intakes, it is advisable to have the intake opening 2.5 m or more above the lake bottom to prevent entry of silts. To minimize entry of floating matter it is recommended to limit the entry velocities to 0.15 to 0.2 m/s.

8.1.2 River intakes

The river intakes, dependent on the formation of the river bed and the amount of total suspended solids (TSP) of raw water could be located onshore with intake line preferably on piles to convey water into the onshore sump for pumping or could be a simple offshore jetty structure to support low head borehole pumps or high pressure centrifugal pumps as required by the system.

In case of turbid rivers with clayey-sand stratum it is preferred to install low lift borehole pumps preferably in pairs on simple jetty structures with piles complete with screen and delivery pipe conveying the water to presedimentation channels in order to reduce the turbidity to acceptable limits (see 6.2) for irrigational needs. This settled raw water can be supplied directly (1) for irrigational and other non-potable needs of the residential houses or plants (fire-fighting etc.), (2) can be transmitted to water treatment plant for potable needs, thus decreasing the initial and operational costs of required clarification and filtration. Generally the mouth of intake should be one(1) meter higher than river bottom level.

8.1.3 Well intakes

Ground water utilization is mainly through open wells, tube wells, springs and "Ghanats". For estimation of groundwater flow the Darcy's law indicates that flow in water-bearing sands varies directly with the slope of the hydraulic gradient.

8.1.4 Sea water intake for desalination plants

Increasing water consumption and depletion of existing sweet water resources has led to considerable interest in conversion of saline or brackish waters. The saline water intake level preferrably should be at least 3 meters below sea-water level as the quality of sea water at shallower depths are more saline. Consequently this water is transformed into potable water by desalination or distillation processes.

8.1.5 Pumping tests of wells

Information on the characteristics of the water bearing formations and the well should be obtained by conducting pumping tests performed in observation wells.

9. METHODS OF DISTRIBUTION-GENERAL

Water can be distributed to consumers through pipes in three ways, as local conditions and other considerations would permit.

9.1 Gravity Distribution

Whenever the source of supply is a lake or impounding reservoir at some elevation above the consumers' so that sufficient pressure can be maintained in the mains for domestic, industrial and fire fighting needs, this is the most reliable and cheapest method. However the main pipeline leading from the source to the town should be well safeguarded against accidental breaks. Motor pumpers might be needed for fire fighting purposes.

9.2 Distribution of Water Supply by Means of Pumps with More or Less Storage

In this method of direct supply to consumers, the excess water pumped during periods of low consumption is stored in elevated tanks or reservoirs. During periods of high consumption, the stored water is drawn upon to augment that of pumped supply. This method allows fairly uniform rates of pumping and usually is economical because of two-directional flow which normally keeps the pipe sizes of the mains a little lower than one-directional flow systems and because of the fact that pumps can be operated at their rated capacity.

A variation to this method, still by means of pumping and storage is the method of direct supply of drinking water to high level tanks and from there onto consumers.

In this method, drinking water is being pumped from pumping station through different feeders or trunk mains to each of the high level storage tanks positioned at the center of groups of houses. From there on, through a network of distribution pipes, the drinking water of the tanks under their static pressure is being consumed by the community. For details of elevated tanks see IPS-G-CE-420.

9.3 Distribution of Water by Means of Direct Pumping without Storage

In this method the pumps force water directly into the mains with no other outlet other than the draw-off points where water is actually consumed. This method is the least desirable system for drinking water supply. But it is the recommended system for irrigation water supply which should have a completely separate distribution network of its own whenever the quality of water supplied to irrigational draw-off points and other non-potable used is inferior to that of drinking water.

In this direct pumping method without storage, as consumption varies, the pressure in the mains would fluctuate. Hence to cope with the varying rate of consumption several pumps usually 4 to 6 in number should be provided in each pumphouse allowing 50% safety factor so that in a pumphouse with 6 installed pumps, four of them in series can meet the peak demand. An advantage of direct pumping is that a high pressure fire service pump can be provided and operated in times of large fires to increase the water pressure to any desired level that the mains can withstand.

10. PREFERRED PIPE DISTRIBUTION SYSTEM

Whenever a reliable municipal water supply system exists, purchase of such water together with associated water supply services whether metered at source of use (dwelling) or at the boundary of private housing development should be preferred. But if water winning, treatment and supply to plants and housing developments is the responsibility of the Company, the following supply system of water distribution is recommended.

10.1 Irrigation Water (Non-Potable Water) System

a) Intake from turbid river

In such a case the requirements and recommendations set-out in clauses 6.2 and 9.3. i.e. distribution of settled raw water by means of direct pumping without storage (within distribution network) is preferred.

As regards the pattern of network of pipes within network of streets, the gridiron pattern with central or looped feeder is preferred. The gridiron network of pipes normally with single mains of 100-150 mm at one side of roads would suffice. The tree system or branching pattern with dead ends would be permitted temporarily on the outskirts of the community, in which ribbon development follows the primary arteries of roads and streets but tees with plugs should be provided at dead ends with an aim to have gridiron pattern at a later phase.

b) Intake from well, lake or reservoir

In such a case, it is recommended to have one distribution system for both potable and non-potable needs as set-out in clauses 9.1 and 9.2 with gridiron pattern of network.

The minimum pipe size of distribution mains, ordinarily, should not be less than 150 mm with dual mains, one at each side of the roads.

10.2 Drinking Water (Potable) System

a) Intake from turbid river

Whenever the source of water is a turbid river, the river intake facilities together with sedimentation channels should be sized for total water requirements i.e. potable and non-potable needs of the water supply project so that part of the settled raw water that meets the quality requirements of clause 6.2 be conveyed to the water treatment plant as stated in clause 8.1.2(2) for further treatment.

The separate distribution system of drinking water meeting the quality requirements of clause 6.1 should be designed in accordance with guidances given in clause 9.2 adopting one of the alternative storage methods as appropriate.

b) Intake form well, lake or reservoir

In such a case as indicated in 10.1(b) only one distribution network should be provided for both potable and non-potable needs and the recommendations of clauses 9.1 and 9.2 are applicable dependent on the local conditions. As regards the pattern of network of distribution mains, the dual mains not less than 150 mm one at each side of the roads is preferred for both cases of (a), and (b).

11. DESIGN OF WATERWORKS DISTRIBUTION SYSTEM

A waterworks distribution system, dependent on whether it is a gravity distribution or pump distribution (see clause 8.1 and 8.2), includes pipe network, storage of some sort, pumping station and components such as valves, fire hydrants etc.

Once the best layout of water distribution system as required in a specific project based on general recommendations set-out in this Standard is decided, the design of its features should be made in accordance with applicable design criteria given hereunder.

11.1 Design of Pipe Distribution Network

The design principles of pipe distribution network supplying potable or non-potable water to communities or plants as regards hydraulics are the same. The differences are in design criteria and design of some of the components that are needed in one system and not or less needed in another.

11.1.1 Description of distribution system

Apart from water intake facilities, the water distribution systems generally comprise of:

a) The primary feeders or arterial mains that carry large quantities of water from distribution pumphouse or natural artificial reservoirs (gravity supply system) to high level tanks simultaneously connected to consumers or not as described in clause 9.2.

b) The secondary feeders may be included in the pipe network to carry considerable amounts of water from the primary feeders to the various areas with looped pattern for normal supply and fire fighting.

c) The small distribution mains form the bulk of the gridiron network supplying water to service pipes of residences and other draw-off points. Ordinarily the pipe sizes of distribution mains should not be less than 150 mm, with the cross pipes also 150 mm at intervals of not more than 200 m.

11.1.2 Factors affecting design of water distribution network

Topography of the land will affect pressure, while existing and expected population densities, and commercial and industrial needs, will affect both pipe size and the location and capacity of storage tanks.

For the preliminary layout of the distribution network, the city or town road layout of the housing project can be utilized.

The plan of distribution mains should allow for expected future expansions and population growth at execution phases.

11.2 Design Criteria

11.2.1 Rates of water use

In the absence of recorded actual water consumption rates in identical projects, the average rates quoted hereunder can be used for design of distribution networks of residential communities:

a) Drinking water

- 250 litres/person per day for moderate climate regions.
- 350 litres/person per day for hot climate regions.

For detailed typical rates of water use for various establishments than can be used for design of building piping refer to Table 3.

TABLE 3 - TYPICAL RATES OF WATER USE FOR VARIOUS ESTABLISHMENTS

USER	RANGE OF FLOW, L/(PERSON OR UNIT).d
ASSEMBLY HALL, PER SEAT	6-10
AUTOMOBILE SERVICE STATION:	
PER SET OF PUMPS	1800-2200
PER VEHICLE SERVED	40-60
COUNTRY CLUB:	
RESIDENT TYPE	300-600
TRANSIENT TYPE, SERVING MEALS	60-100
DWELLING UNIT, RESIDENTIAL:	
APARTMENT HOUSE ON INDIVIDUAL WELL	300-400
APARTMENT HOUSE ON PUBLIC WATER SUPPLY, UNMETERED	300-500
BOARDING HOUSE	150-220
HOTEL	200-400
LODGING HOUSE	120-200
PRIVATE DWELLING ON INDIVIDUAL WELL ON METERED SUPPLY	200-600
PRIVATE DWELLING ON PUBLIC WATER SUPPLY, UNMETERED	400-800
FACTORY, SANITARY WASTES, PER SHIFT	40-100
HOSPITAL	700-1200
OFFICE	40-60
RECREATION PARK, WITH FLUSH TOILETS	20-40
RESTAURANT (INCLUDING TOILET):	
AVERAGE	25-40
KITCHEN WASTES ONLY	10-20
SCHOOL:	
DAY, WITH CAFETERIA OR LUNCHROOM	40-60
STORE:	
FIRST 7.5 m OF FRONTAGE	1600-2000
EACH ADDITIONAL 7.5 m OF FRONTAGE	1400-1600
SWIMMING POOL AND BEACH, TOILET AND SHOWER	40-60

b) Irrigation water

b-1) Hot climate regions:

- 100 m^3 per day per hectare of planted areas such as lawns, cultivation etc. - for hot climate regions.

Irrigation draw-off water points (20 mm or ¾" taps) shall be provided 15 meters apart in planted areas of housing schemes so that with a ten meter long flexible hose pipe all planted areas may be reachable.

- 400 litres per day per dwelling or 20 litres per sq. meter of concrete pavement for courtyards washing.

- 100 litres per minute lasting for 15 minutes for car washing once a week.

- 12 litres per ton for cooling capacity for cooling of central air conditioning plants and/or A/C units.

- Fire fighting water, in separate systems of potable and non-potable needs, shall be provided from settled raw water system through fire hydrants that are 100 meter apart at a rate of 8 m^3 per minute for a duration of maximum ten hours with fire hydrants each having two hose couplings. The max. amount of water required for control of an individual fire is 4.5 m^3/min. in large communities. In residential districts the required flow ranges from 1.9 m^3/min. to 9.5 m^3/min. A single hose stream at 1.4 kg/cm^2 pressure is considered to be 1 m^3/min. Hence, at least 8 hydrant hose connections taken form 4 fire hydrant stands should fight each individual heavy fire.

b-2) Moderate regions:

- 50 m^3 per day per hectare of grass plantation.
- 300 litres per day per dwelling or 15 litres per sq. meter of concrete pavement for courtyard washing.
- For car washing the same as in hot climates.
- For fire fighting the same as in hot climates.

Note:

In a water distribution system that provides for both potable and non-potable needs, the rates of water use should be added up.

11.2.2 Velocities

Velocities at peak flows in all feeders and distribution mains usually do not exceed 1 m/s with 2 m/s as the upper limit, which may be reached near large fires.

11.2.3 Pressure ratings

There are wide differences in the pressures maintained in distribution systems dependant on limitation of building heights imposed by the municipality and fire fighting factor.

Table 4 gives the required pressures for different height limitations and fire fighting source and means.

TABLE 4 - PRESSURES

BUILDING HEIGHTS AND FIRE FIGHTING FACTOR	PRESSURE IN kPa
RESIDENTIAL DISTRICTS HAVING HOUSES MAX. TWO STORIES IN HEIGHT FOR ORDINARY SERVICE (FIRE FIGHTING FROM OTHER SOURCE)	150 to 300
RES. DISTRICTS WITH BUILDING HEIGHTS LIMITED TO FOUR STORIES BUT WHERE DIRECT HOSE STREAMS ARE USED FOR FIRE FIGHTING	400 to 500
SAME AS ABOVE, BUT FOR COMMERCIAL DISTRICTS	500 to 600 (SEE ALSO NOTE 1)
IN COMPANY OWNED AND OPERATED HOUSING AREAS WITH MAX. THREE STORY BUILDINGS AND SEPARATE SETTLED RAW WATER SYSTEM FOR IRRIGATION AND FIRE FIGHTING	MIN. 2 kg/cm^2 = 220 kpa FOR DRINKING WATER MAINS (SEE NOTE 2) AND 500 kpa FOR SETTLED RAW WATER NETWORK
REQUIRED PRESSURE IN SEPARATE SETTLED RAW WATER DISTRIBUTION FOR IRRIGATION AND FIRE FIGHTING	500

Notes:

1) During heavy fire demands when a pumper is used a drop in pressure to not less than 200 kPa is permitted in the vicinity of fire in commercial districts.

2) The practical available pressure at the highest and farthest tap of any building with design pressure of 2 kg/cm^2 would not be less than 0.5 kg/cm^2 i.e. five meter of water column pressure.

11.2.4 Necessary storage

Water is stored to equalize pumping rates over the day, to equalize supply and demand over a long period of high consumption, and to furnish water for such emergencies as fire fighting or accidental breakdowns.

Elevated storage is furnished in earth or masonry reservoirs situated on high ground or in elevated tanks.

The capacity of the elevated tank or tanks will depend upon the load characteristics of the system, which should be carefully studied before any decision is made. To equalize the pumping rate, i.e., allow a uniform rate throughout the day will ordinarily require storage of 15 to 30 percent of the maximum daily use. Future increases in demand must, of course, be considered.

In the absence of data the maximum daily consumption can be taken as 180 to 200 percent of the annual average. The main functions of elevated storage tanks in order of importance are:

- To discharge water into the mains during peak loads, thus raising the hydraulic grade line in nearby distribution mains, thus economizing on the sizes of mains.

- To provide adequate volume of water having at least 20 meter water pressure for fire fighting purposes.

- Storage may also be needed to equalize demand over a long-continued period of high use, such as a cold period in winter or a dry period in summer. Such storage is particularly needed when wells of limited capacity are the sources of supply or when water must be filtered. In such cases, periodic testing of the quality of stored water is mandatory.

Wherever land at reasonable cost is available at the site of water winning, it is recommended to provide ample storage in the vicinity of source of supply at ground level such as artificial lakes etc., so that the needed disinfection (chlorination etc.) can be done at water purification stage.

The tanks can be equipped with valves which close the entrance pipe when the tank is full and reopen when the pressure in the mains drops during peak demand.

11.2.5 Design flows

The sizing of the pipes in drinking water distribution network shall be designed for a peak demand rate of four times average rate of consumption (see 11.2.1 a), whereas pipes in settled raw water distribution network shall be designed for a peak demand of twice the average rate of predicted flow (see 11.2.1 b).

11.3 Flow in Pipes

Since flow is usually turbulent in pipes used for water supply the friction factors depend upon the roughness of the pipe and also upon the Reynolds number which, in turn, depends in part upon the velocity in the pipe and its diameter.

Various pipe-flow formulas are available to predict headlosses as a function of velocity in pipes, and of these the Hazen-Williams formula (although empirical) is more often used in the design of water distribution systems, however use of equivalent formulas are acceptable when approved by the AR*.

Hazen Williams formula states that: $\mathbf{v = k\,(C)r^{0.63}S^{0.54}}$

in which v is the velocity in the pipe in distance per second, r is the hydraulic radius of the pipe, S is the hydraulic gradient, C is a constant depending upon the relative roughness of the pipe, and k is an experimental coefficient and equal to 0.849 (m/s, m). For values of C coefficient in Hazen-Williams formula refer to Table 5.

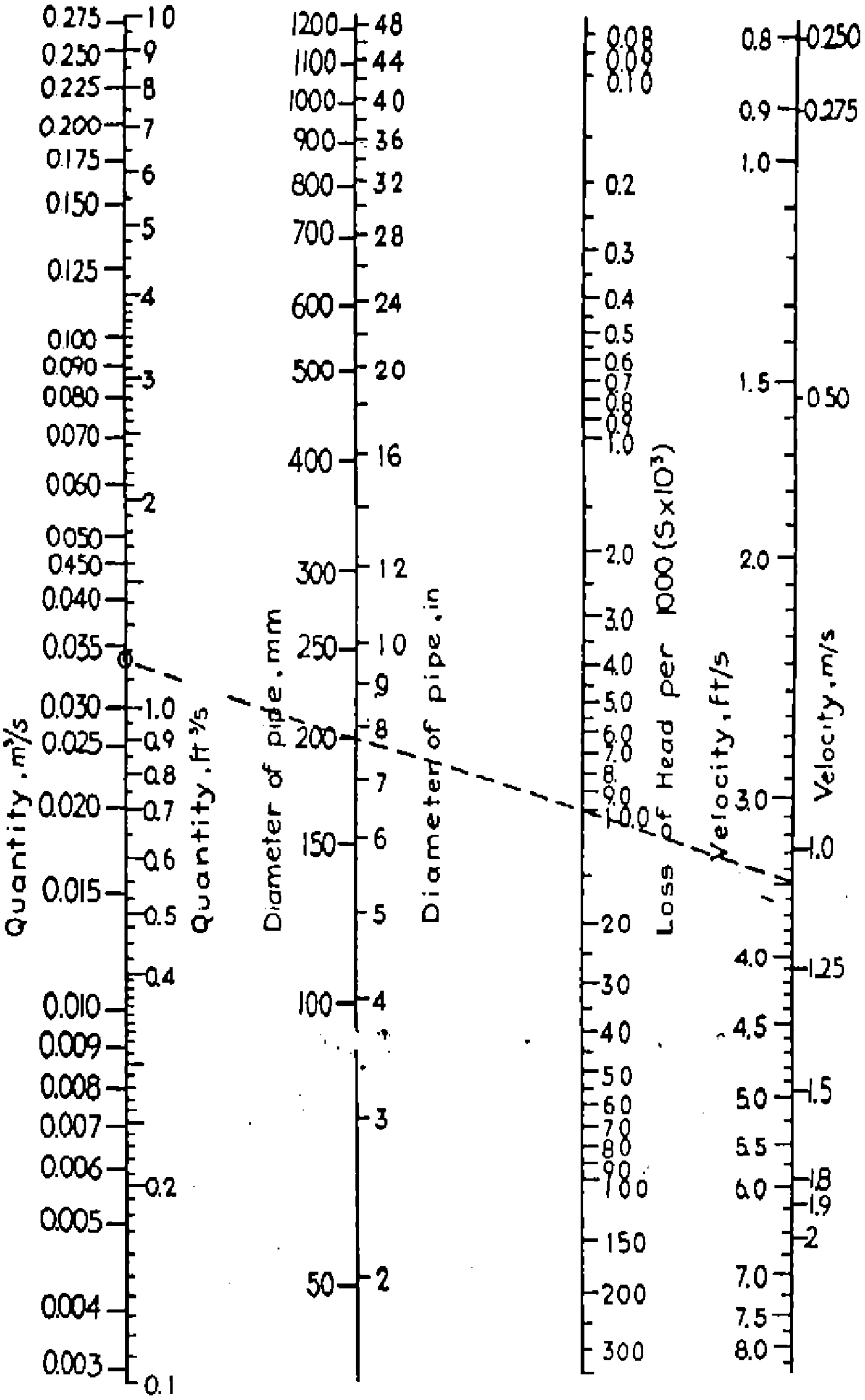
TABLE 5 - HAZEN-WILLIAMS COEFFICIENTS FOR VARIOUS PIPE MATERIALS

DESCRIPTION OF THE PIPE	VALUES OF C
EXTREMELY SMOOTH AND STRAIGHT	140
CAST IRON:	
NEW	130
5 YEARS OLD	120
10 YEARS OLD	110
20 YEARS OLD	90-100
30 YEARS OLD	75-90
CONCRETE OR CEMENT LINED WELDED STEEL, AS FOR CAST-IRON PIPE, 5 YEARS OLDER RIVETED STEEL, AS FOR CAST-IRON PIPE, 10 YEARS OLDER	120-140
PLASTIC	150
ASBESTOS CEMENT	120-140

To be on the safe side the designer can use a value of C = 100 for cast-iron pipe for designing water distribution systems considering this to represent its relative roughness at some future time. This may be too large where very corrosive or incrusting water is encountered. Where such waters are encountered the use of cement lined, plastic, or asbestos cement pipe or treatment of the water to reduce its corrosiveness may be advantageous.

For sizing of pipes, the nomogram shown in Fig. 1 can be used for velocity or flow when pipe size and slope of hydraulic grade line are known and vice versa.

*** AR = Authorized Representative of the Owner.**



FLOW IN OLD CAST-IRON PIPES (HAZEN-WILLIAMS C = 100)
Fig. 1

11.4 Design Procedure

In the design of a new system the pipe sizes should be assumed (see clause 11.1.1) and the system investigated for the pressure conditions that will result from various demand requirements.

On the preliminary layout of the distribution network all the required feeder mains, secondary mains and small distribution mains with distinct line thicknesses indicating at the same time the location of storage tanks, valves, hydrants should be marked. Next the rates of demand for all purposes should be estimated and marked on the appropriate pipe. Then the recommended diameter of distribution mains should be checked and corrected upward on the basis that

$$d = 2\sqrt{Q/\pi v}$$

where v is the assumed velocity ranging from 0.9 to 1.5 meter per second.

Finally, the "Hardy Cross Method of Analysis", can be used which balances either the head losses or quantities. The balancing of head losses is preferred. The pipe flow formulas of Hazen-Williams, Manning or Chezy can be safely used in design of domestic water supply projects.

11.5 Design of Components

The components involved in waterworks distribution system apart from water reservoirs and elevated tanks are the pumps and pumping stations, various types of valves used in the conveyance of water, fire hydrants and arrangement of service pipe i.e. the pipe extending from the main to the consumer’s water meters if any, or extending up to dwelling units isolating main valve just inside the curtilage.

11.5.1 Pumps and pumping stations

Apart from supplies of water originating in mountainous areas that can be furnished to consumers entirely by gravity, usually, however, it is necessary to raise the water by means of pumps at one or more points in the system. Pumps are needed, therefore, to lift water from a lake, reservoir, or river to sedimentation channels or to a water treatment plant, and from thereon another lift will be needed to force the water into the mains and elevated storage tanks. Sometimes a booster pump may be needed at certain points of trunk or feeder mains to keep pressure at desirable levels.

- Design criteria

In pumping stations supplying drinking water in single distribution systems with storage for potable and non-potable needs (see clause 9.2), the installed total pumping capacity including stand-by should be 30 percent more than the peak demand of all seasons.

Whereas the installed total pumping capacity of pumping stations supplying water (mostly settled river water) by direct pumping without storage (clause 9.3), should be 50 percent more than the peak demand of dry weather seasons.

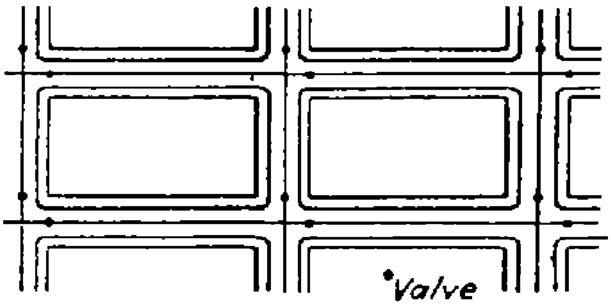
It is good practice to provide 1 or 2 spare pumps and motors in each pumping station over and above the installed stand-by capacities to replace units under repair.

The pumps used in water supply systems are divided into three general classes, reciprocating, rotary, and centrifugal. The reciprocating class typically consists of a piston or plunger which alternatively draws water into a cylinder on the intake stroke and then forces it out on the discharge stroke. The rotary type contains two rotating pistons or gears which interlock and draw water into the chamber and force it practically continuously into the discharge pipe. The centrifugal type has an impeller with radial vanes rotating swiftly to draw water into the center and discharge it by centrifugal force.

The centrifugal or impeller-type pumps are the most used pumps in water engineering field. The duties covered by impeller-type pumps range from the pumping of small flows, minimum 450 litres per minute, against very high heads of maximum 300 meters (generally performed by multistage diffuser pumps) to the pumping of large quantities, say 225 m^3 per minute against very low heads of minimum 1.5 meter.

11.5.2 Valves

Various types of valves are used in conveyance of water. The fields of usefulness of each type together with some design criteria are given in Table 6.



SCHEMATIC LOCATION OF VALVES IN DISTRIBUTION SYSTEM
Fig. 2

Notes:

1) Recommended spacing of valves in a high value district is 150 meters and 250 meters in other districts.

2) Underground valves should be placed in valve chambers see IPS-D-CE-190 & 191.

3) Sluice or gate valves should not be left partially open for long periods as the velocity of the water may erode the seatings.

4) Valves larger than 300 mm (12") require gearing unless the pressure is low.

TABLE 6 - VARIOUS TYPES OF VALVES

ITEM	TYPES OF VALVES	FIELD OF APPLICATION AND SOME TECHNICAL RECOMMENDATIONS
1	GATE VALVES (USA) SLUICE VALVES (U.K) WITH RISING OR NON-RISING STEM AS REQUIRED	COMMONEST AND MOST USED VALVE IN DISTRIBUTION NETWORKS. RECOMMENDED VALVE LOCATIONS ARE SHOWN IN FIG. 2 (SEE ALSO NOTES).
2	GLOBE VALVES	SELDOM USED IN WATER DISTRIBUTION NETWORK BECAUSE OF THEIR HIGH HEAD LOSS CHARACTERISTICS. THEY CAN BE USED IN HOUSEHOLD PLUMBING WHERE THEIR LOW COST OUTWEIGHS THEIR POOR HYDRAULICS.
3	FLOAT VALVES	USED ON THE INLETS TO SERVICE RESERVOIRS AND TANKS.
4	CHECK OR REFLUX OR NON-RETURN VALVES	ONE DIRECTIONAL NON-RETURN FLOW VALVES CLOSED AUTOMATICALLY BY FLUID PRESSURE. USED TO PREVENT REVERSAL OF FLOW ON GRAVITATIONAL SUPPLY MAINS (ALSO IN EFFLUENT DISPOSAL RISING MAINS), OR WHEN PUMPS ARE SHUT DOWN. THEY ARE INSTALLED ALSO AT THE END OF A SUCTION LINE TO PREVENT DRAINAGE OF SUCTION LINE AND CREATION OF VACUUM.
5	FOOTVALVES	CHECK VALVES INSTALLED AT ENTRY OF SUCTION LINES.
6	BUTTERFLY VALVES	LESS COSTLY THAN GATE VALVES, USED IN BOTH LOW PRESSURE APPLICATIONS AND IN FILTRATION PLANTS. IN LARGE PIPE OPERATIONS HAVE NUMEROUS ADVANTAGES OVER GATE VALVES INCLUDING LOWER COST, COMPACTNESS, MIN. FRICTION WEAR AND EASE OF OPERATION. SHOULD NOT BE USED FOR CONVEYANCE OF SEWAGE EFFLUENTS OF ALL KIND.
7	PRESSURE REGULATING-REDUCING VALVES	THESE AUTOMATICALLY REDUCE PRESSURE ON THE DOWN-STREAM SIDE TO ANY DESIRED MAGNITUDE AND ARE USED ON LINES ENTERING LOW ALTITUDE AREAS OF A CITY WHERE, WITHOUT SUCH REDUCTION, PRESSURE WOULD BE TOO HIGH. NOT APPLICABLE IN OIL INDUSTRIES' SMALL HOUSING COMMUNITIES.
8	PRESSURE-SUSTAINING VALVES	SIMILAR TO PRESSURE-REDUCING VALVES, EXCEPT THAT, INSTEAD OF TENDING TO CLOSE WHEN THE DOWNSTREAM PRESSURE RISES, THEY TEND TO CLOSE IF THE UPSTREAM PRESSURE FALLS, THUS MAINTAINING A MORE OR LESS CONSTANT UPSTREAM PRESSURE.
9	ALTITUDE VALVES	USED TO CLOSE AUTOMATICALLY A SUPPLY LINE TO AN ELEVATED TANK WHEN THE TANK IS FULL. FLOW FROM THE TANK IS PERMITTED WHEN A SELECTED AND SET LOW PRESSURE BELOW THE VALVE INDICATES THAT WATER FROM THE TANK IS REQUIRED. THIS KIND OF VALVE CAN BE USED AT THE FOOT OF INLET PIPE OF WATER TANKS IN DISTRIBUTION SYSTEM OF CLAUSE 9.2.
10	AIR AND AIR-RELIEF VALVES	REQUIRED TO DISCHARGE AIR WHEN A MAIN IS BEING FILLED AND TO ADMIT AIR WHEN IT IS BEING EMPTIED. THE INLET TO THE AIR VALVE SHOULD BE PROVIDED WITH A SLUICE VALVE TO ISOLATE IT FOR REPAIRES. AIR VALVES MUST BE FIXED AT HIGH POINTS ON THE PIPELINE AND CLOSE TO MAIN VALVES.

(to be continue)

TABLE 6 - (continued)

ITEM	TYPES OF VALVES	FIELD OF APPLICATION AND SOME TECHNICAL RECOMMENDATIONS
11	WASH-OUT VALVES	PROPORTIONAL TO THE MAINS AND LOCATED ADJACENT TO LARGE OPEN DRAINAGE CHANNEL (MAJOR NULLAHS). IN ORDER TO ENABLE A PARTICULAR LENGTH OF THE PIPE TO BE EMPTIED AS REQUIRED.
12	SLUICE GATES (USA) OR PENSTOCKS (U.K)	A BARRIER PLATE FREE TO SLIDE VERTICALLY ACROSS A WATER OR SEWAGE CHANNEL, OR AN OPENING IN A LOCK GATE

Note:

For material specification of valves and hydrants ets. refer to IPS-M-CE-345.

11.5.3 Fire hydrants

Hydrant spacing is dictated by the required fire fighting water flow because the capacity of a single hydrant is limited. A single hose stream is considered to be approx. 1 m^3/min. that serves a minimum of 3720 m^2 area. Thus the recommended spacing of fire hydrants is approximately 60 m when installed on drinking water networks and 100 m apart when installed on separate settled raw water networks. Ordinarily hydrants are located at street intersections where streams can be taken in any direction. In high value districts additional hydrants may be necessary in the middle of long blocks. The fire hydrant stands diameter in cold climate regions should be 150 mm and in hot climates 100 mm. For std. drawing refer to IPS-D-CE-180 and 181.

11.5.4 The service pipe

The pipe extending from the distribution mains (preferably small distribution mains) to the housing or dwelling's water meter, or stop valve with no meter, is known as the service pipe. The service pipes must be durable to minimize unsightly breaks in the high-grade paving for repairs.

In order of preference, copper-high density and high strength flexible plastic pipes and or rigid PVC and galvanized iron pipes with screw joints can be used for service pipes. If flexible pipe materials are used it is recommended to provide steel sleeves for their protection just after the corporation cock or ferrule tapping. The ferrule tappings should be located on the top section of the mains preferably slightly inclined toward curtilage of housing unit. Thus, a flexible connection could be obtained more easily and the possibility of any sediment entering form the main to the service pipe will be reduced. The size of service pipe should not be less than 20 mm (¾") to insure good pressure in the building. If for any reason its length be more than 10 meter, a 30 mm ferrule is needed for a single dwelling unit, 40 mm for a two family house and 50 mm for an apartment house having not more than 25 families.

Corporation cocks or ferrules requiring over a 50 mm hole are not ordinarily tapped into mains of even adequate size.

For ferrule connections to mains, the following limitations should be respected.

For 100 mm mains maximum ferrule size permitted should be less than 20 mm; for 150 mm, 25 mm; for 200 mm, 30 mm; for 250 mm, 40 mm and for 300 mm, 50 mm.

11.6 Corrosion Prevention

Any corrosion prevention method considered in the design and installation of pipelines should comply with the following IPS standards:

IPS-E-TP-760	"Corrosion Consideration in Design"
IPS-E-TP-350	"Linings"
IPS-E-TP-270	"Coatings"
IPS-C-TP-820	"Electrochemical Protection (Cathodic & Anodic)"
IPS-C-TP-742	"Corrosion Consideration During Fabrication and Installation"
IPS-C-TP-274	"Coating"
IPS-C-TP-352	"Lining"