Z.16025/1/2020-CPHEEO
Government of India
Ministry of Housing and Urban Affairs
{CPHEEO}

Nirman Bhawan, New Delhi
Dated: 6th March, 2023

To,
The Principal Secretary /Secretary (UD/PHED)
All States/UTs.

Subject: Addendum to the "Guidelines for Planning, Design and Implementation of 24x7 Water Supply Systems", December 2021.

Dear Sir/Madam,

I am directed to forward the Addendum to the "Guidelines for Planning, Design and Implementation of 24x7 Water Supply Systems", December 2021, published by the Ministry. This addendum shall be read in conjunction with the above said published Guidelines.

This issue with the approval of the Competent Authority.

Yours faithfully,

Ramakant

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Deputy Adviser (PHE)
Email: dr.ramakant@nic.in

Encl: As above.

Copy to:
(i) PPS to AS(AMRUT), MoHUA for kind information to AS(AMRUT).
(ii) PPS to Adviser (PHEE), CPHEEO & Chairman of Expert Committee & NTF for kind information to Adviser (PHEE).
(iii) Technical Head of PHED/ Jal Nigams/ Jal Boards/Water Supply and Sewerage Boards for information and necessary action.
(iv) Members of "Expert Committee for Preparation of Advisories" for kind information.
(v) Members of "National Task Force on 24x7 Water Supply" for kind information.

Addendum to the "Guidelines for Planning, Design and Implementation of 24x7 Water Supply Systems" Published in December, 2021

This addendum may be read in conjunction with the "Guidelines for Planning, Design and Implementation of 24x7 Water Supply Systems" December, 2021, published by CPHEEO, Ministry of Housing and Urban Affairs, Govt. of India. The following modified content shall be referred to along with the existing Guidelines.

Chapter 2: Design Parameters, **Section 2.3 Customer's Underground Tank -** Residual head of 17m shall be adopted as 21m for Class I & II cities/towns and 12m residual head shall be adopted as 15m for Class III towns and below. Thereafter, in all the sections and all appendix, the modified residual head shall be read and adopted.

Chapter 2: Design Parameters, Table 2.1-Recommendations and salient features of this guideline for capital works, S. No. 6 - Total demand, S. No. 14 - GIS Mapping, S. No. 23 - Design of distribution system and S. No. 42 (newly added) - Design of buried pipelines in seismic active areas: The following modification in content shall be read in inclusion with the existing Table 2.1.

S. No.	Parameters	Conversion from present intermittent stage to 24x7 water supply systems	Remarks
6.	**Total demand**	In addition to domestic demand, commercial demands (hotels, lodges, hospitals, market etc.) and institutional demand (schools, colleges, offices theatres etc.) duly extrapolated for different stages should be added as an external or additional loads to the respective nodes in distribution system. In the absence of consumer survey, present demand due to semi-commercial to the tune of about 5-10% of intermediate demand (residential) may be considered base year depending on the nature of the town. This demand may be increased at the rate of 1% per year to arrive at future demands after 15 and 30 years. Total demand should be computed by adding following losses: Total losses in the system should not exceed 15%. Indicative, break up of	Consumer survey of the city is mandatary for commercial, institutional, and industrial establishments (such locations can be easily identified using Google earth). Consumer survey helps to ascertain requirement of consumer meters, identifying suspected illegal connections and for shifting of connections from main line. Semi-commercial demands include micro industries, market, shops, vegetable market, traders, hawkers, non-residential tourists, picnickers, religious places etc.

S. No.	Parameters	Conversion from present intermittent stage to 24x7 water supply systems	Remarks
		losses is as below: (a) Head work to inlet of WTP should not be more than 1% (b) In WTP losses should not be more than 3% (c) Outlet of WTP to Various ESRs losses should not be more than 1% In distribution system losses should not be more than 10%	After deciding these values of demands, hydraulic modelling (design of distribution system) should be taken up.
14.	**GIS Mapping**	It is necessary to use GIS system. GIS mapping of all the existing, proposed and executed infrastructure is required. GIS simulating modelling should be adopted. GIS maps of ward boundary should be adopted for estimating demand by future ward wise population density method.	Expanse of urban project from source to actual city and spread of the city is large, hence, it is not possible to manually feed the values of ground elevations and demands to hundreds of nodes of large network. Training courses on GIS should be organized for capacity building of ULB's engineers and planners.
23.	**Design of distribution system**	Design methodology in details is given in Chapters 5. Velocities in pipes need to be increased to optimum level and diameters can be reduced without use of costly software.	Strategic points such as maximum and minimum ground elevation and the farthest point should be marked on the drawings of operational zones.
42	**Design of buried pipelines in seismic active areas**	It is suggested to use ductile fittings of the segmented steel pipelines (e.g., water pipelines) in high seismic areas. Also, PE pipes provide effective, cost-efficient solutions for earthquake pipeline design. Further reference may be seen from "IITK-GSDMA guidelines for seismic design of buried pipelines provisions with commentary and explanatory examples" available at http://www.iitk.ac.in/nicee/IITK-GSDMA/EQ28.pdf	The seismic hazards which are directly related to pipeline failure can be classified as: 1. Permanent ground deformation related to soil failures: • Longitudinal and Transverse permanent ground deformation • Landslide 2. Buoyancy due to liquefaction 3. Permanent ground deformation related to faulting 4. Seismic wave propagation

Chapter 2: Design Parameters, Table 2.2 - Recommendations and Salient Features for Operation & Maintenance, S. No. 13 (newly added) - Digital Twin

S. No.	Parameters	Conversion from present intermittent stage to 24x7 water supply systems	Remarks
13	**Digital Twin**	Digital twin is recommended to utilize the data generated by the SCADA. The water infrastructure digital twin should be able to bring SCADA, GIS, hydraulic modeling, consumer information and historical data into a cloud based single platform to deliver cost-effective, real-time operations management, energy management and asset management.	A digital twin is a virtual representation of water supply system that spans its lifecycle. It is updated from real-time data, and uses simulation, machine learning and reasoning to help decision-making.

Chapter 4 Operational Zone and DMA, Section 4.12 (newly added) - Designing House Service Connections, Section 4.12.1 - Medium density Polyethylene Pipes, Section 4.12.2 - Polyethylene-aluminium-polyethylene pipes and Section 4.12.3 – Saddle sets in House Service Connections: may be read in inclusion with Chapter 4 as follows:

4.12 House Service Connection

Distributing water with 100% consumer metering is most essential. Hence, consumer metering is necessary. Water supply to a house begins with connection of the service pipe with water supply mains. The Service connection pipe & internal plumbing shall conform National Building Code or related IS code.

4.12.1 Medium Density Polyethylene Pipes (MDPE)

The medium density Polyethylene Pipes (MDPE) are now being manufactured in India conforming to ISO specifications (ISO 4427 and BS 6730 - 1986) for carrying potable water. However, no BIS is available for these pipes. The MDPE pipes are being used for consumer connection pipes as an alternative to GI pipes. The Polyethylene material used for making the MDPE pipes conforms to PE 80 grade and the MDPE pipes when used for conveying potable water does not constitute toxic hazard and does not support any microbial growth. Further, it does not impart any taste, odour or colour to the water.

The Polyethylene material conforms to PE 80 grade. The MDPE pipes are colour coded black with blue strips in sizes ranging from 20 mm to 110 mm dia for pressure class of PN3.2, PN4, PN6, PN10 and PN16. The maximum admissible working pressures are worked out for temperature of 20 degrees centigrade as per ISO 4427. The pipes are supplied in coils and minimum coil diameter is about 18 times diameter of the pipe.

MDPE compression fittings made of PP, AABS, UPVC are also available in India for use with MDPE pipes. The materials used for the fittings are also suitable for conveying potable water like MDPE pipes. The jointing materials of fittings consists of thermoplastic resins of Polyethylene type, NBR 'O' ring of Nitrile and Clamp of Polypropylene, copolymer body, Zinc plated steel reinforcing ring, nuts and balls of special NBR gasket. The MDPE pipes are lightweight, robust and non-corrodible and hence can be used as alternative material for consumer connections. Since the pipes are supplied in coils, there will be no joints under the roads and bends are avoided resulting in fast, simple and efficient jointing.

1.12.2 Polyethylene–Aluminium–Polyethylene (PE-AL-PE)

Polyethylene–Aluminium–Polyethylene (PE-AL-PE), called Composite Pipe, conforming to IS-15450-2004 (revised in 2022) is suitable for House Service Connections. Multilayer Composite pipe delivers new standards of quality in the field of water supply and is being used for house service connection pipe as a better alternative. The PE-AL-PE Multilayer composite pipe comprises one aluminium layer, tie layers of polymeric adhesive and inner and outer layers of High density Polyethylene (HDPE). The inner and outer polyethylene layers are bonded to metallic aluminium layer by polymeric adhesive during manufacturing of pipe. It is light, strong and does not support corrosion. BIS has approved PE-AL-PE. Pipes for dia. (outer dia.) ranging from 14mm to 75mm which may be used in service connection pipes for commercial & industrial establishments and bulk demand for residential complexes/ group of households.

(Figure 4.14: PE-AL-PE Pipe)

These pipes are non-corroding thermoplastic layers resist the most aggressive water conditions and hot-soil environments. The PE-AI-PE composite pipe are pressure rated for maximum water pressures of 13.8 Kg/cm2 at 23°C, 11 Kg/cm^2 at 60°C and 6 Kg/cm^2 at 80°C. With a Hazen- Williams flow coefficient of C-150, these pipes will not corrode or allow algae build-up inside the pipe which can increase friction losses. Long term pressure rating of these pipe includes safety factor of 2:1. Hence the PE-AL-PE pipes easily handles pressure increases created by surges in a water service application.

The PE-AL-PE pipe has resistance to chlorine attack than other non-composite pipes because of the aluminium middle layer. These pipes are lightweight, robust and non-corrodible and hence can be used as alternative material for consumer connections.

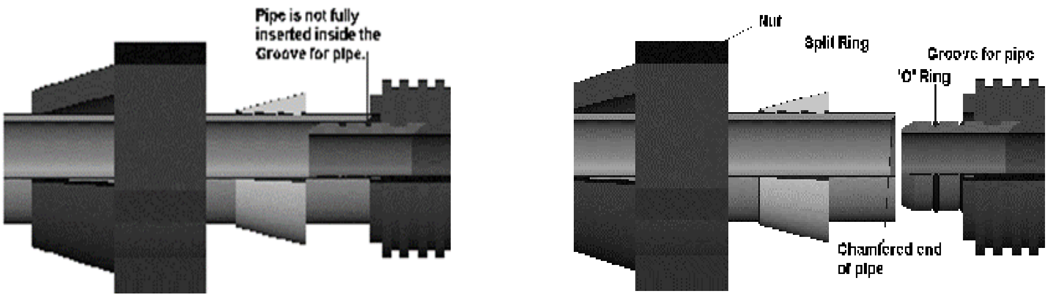


Figure 4.15: Jointing of PE-AL-PE Pipe

4.12.3 Saddle sets in House Service Connections

Major portion of leakages occur in house service connections. At present, saddle set with female threaded nipple is used in House Service Connection (HSC) and this practice results into high leakages at the ferrule points and contamination of water in the pipeline. These leakages from HSC can be controlled & reduced by using monolithic saddles with compression fittings. There are two types of saddles used in the distribution system for HSC. One is service saddle with inbuilt compression fittings manufactured using injection molded/electro fused technology for plastic pipes. The other type is strap saddle used for metallic pipes.

The monolithic service saddle is manufactured out of alloy of virgin polypropylene (PP) and is made with special additives that provide UV protection. It has higher mechanical strength and ensures smooth flow. The service saddle is available in blue and black color. The PP service saddle set is used for PVC/HDPE and other non-metallic pipes. For metallic pipes, strap saddle, which is made of metal, is used. Both service saddle and strap saddle are used upto 200 mm dia pipe. These saddles are suitable for house service connections in urban areas.

Figure 4.16: Monolithic service saddle for non-metallic pipes

Figure 4.17: Strap saddle for metallic pipes

Department of Drinking Water and Sanitation, Ministry of Jal Shakti has recommended adoption of Integrated Clamp saddle set with Flow Control Valve (FCV) in house service connection in rural areas under Jal Jeevan Mission 2 to ensure equity and efficiency in water supply services. The integrated saddle with FCV is designed for 5 LPM (±0.75 lpm) discharge at 0.50 pressure and not exceeding the flow of 7 LPM (±0.75 LPM) at 1 bar (10m Head) pressure. The integrated saddle set is manufactured using injection moulded /electro fused technology. FCV is manufactured using SS316 solid steel bar. FCV/NRW can be designed for higher flow control discharge beyond 7 LPM subject to distribution design for effective water needs beyond 7.0 LPM. The terminal pressure of 7m is recommended in rural water supply distribution network where no FCV is used in the HSCs and 12m is recommended in the rural water supply distribution network, where FCV is used in the HSC, considering the head loss in the FCV at the ferrule point.

However, the integrated saddle set with FCV may be avoided in the HSCs in Urban areas as it may lead to increased head loss at the ferrule point and affect the recommended terminal pressure of 21m for Class I & II Cities and 15m for other cities and towns.

Chapter 8 (newly added) Planning & Design of 24x7 Water Supply for one Ward/ DMA or 2,000 Connections may be read in inclusion with the existing Guidelines.

Chapter 8
Planning & Design of 24x7 Water Supply for one Ward or 2,000 Connections

8.1 Introduction

As per operational guidelines of AMRUT2.0 issued by Govt. of India, "all 500 AMRUT cities are mandated to undertake reforms for water conservation including 24x7 water supply projects with 'Drink from tap' facility. It is one of the admissible components and these projects should cover at least one ward or DMA with at least 2,000 households in the contiguous manner. However, during the First Regional Workshop on 24x7 Water Supply Systems on 29^{th} & 30^{th} Sept 2022 at Puri, this limitation is removed, and the city can now plan, design and execute 'Drink from tap' facility with 24x7 water supply for the entire city. Projects costing up to 20% of the project fund allocation for water supply projects in AMRUT cities may be taken up for 24x7 water supply. Additional funding for such projects will be admissible in form of reform incentive."

8.2 Steps for Formation of Zone/DMA

City may directly plan and design for one ward/ zone/ DMA having connections of 2,000. Following steps are required:

(i) Carryout door to door consumer survey including geo tagging (latitude and longitude) of consumer meters and identifying illegal connections, assessing number of connections of nondomestic and high-rise buildings, assessing number of domestic and bulk meters.

(ii) Schools, colleges, hospitals, hotels, etc. are called as the "point loads." Survey must be carried out for these point loads and their location (in the point form) should be shown on GIS map. Such locations can be easily identified using Google earth. Demand of each point load should be computed. Hydraulic model of these point loads shall be separately built-up and then incorporated into the main Hydraulic model. These points (nodes) shall be connected to the nearest pipes in the main Hydraulic model. In this way the point loads are incorporated into the Hydraulic model.

(iii) A GIS map of distribution system should be made ready.

(iv) Identify one existing/ new service tank from the selected ward with at least 2,000 connections in the adjoining manner that can supply water on 24x7 mode.

(v) Identify existing service tank in the selected ward that can render 21m nodal pressures.

(vi) If 21m nodal pressure not achieved for existing tank, then plan and design for online boosting/ direct pumping. It is observed that the electricity charges are low due to low marginal head of the pump.

(vii) Location of this new tank shall be marked on Google and later its Keyhole Markup Language (KML) file shall be used for inserting it in the Hydraulic model. The minimum capacity of the new tanks shall be one-third of the demand (of ultimate stage of 30 years) that tank serves.

(viii) If land for new tanks is not available, then the distribution system shall be designed for direct pumping from clear water sump of WTP. This sump shall have capacity of 2 hours detention time.

(ix) The road center lines shall be digitized on the satellite image of city. This satellite image may be obtained from-

  a. National Remote Sensing Agency (NRSA)
  b. Online service of the GIS software
  c. Drone image

(x) Retrofitting of the existing pipe network shall be carried out as detailed in Appendix G. This retrofitting is required for determining the boundaries of Operational zone, pressure zones and DMAs.

(xi) Assessing number of consumer's sumps which can be removed after commissioning of project.

(xii) Mass balance curve should be drawn to understand the behaviour of the tank so that the tank neither empties nor overflows as per required water demand.

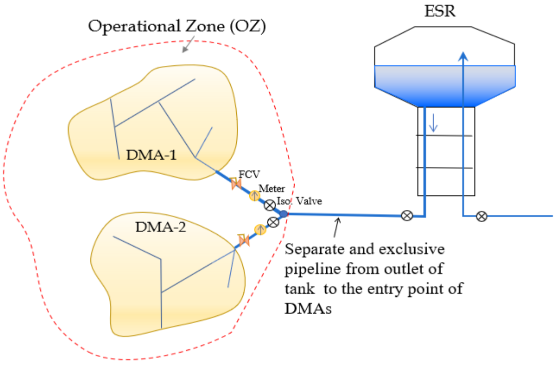


Figure 8.1: Arrangement of pipes from tank

(xiii) Create pressure zones by the retrofitting procedure as explained in Appendix G.

(xiv) Re-engineer and Retrofit network in the operational zone for obtaining nodal pressure of 21 m or 15m as the case may be.

(xv) Plan and design pipe network for the future sub zones/ DMAs.

(xvi) From the service tank, there should be separate and exclusive pipeline to the entry point of the DMA as shown in Figure 8.1.

(xvii) If new tank is to be constructed, then separate outlet from the tank shall be provided to each DMA.

(xviii) Isolation valve, Bulk meter and FCV/ PRV (if required) shall be installed on this pipeline.

(xix) Run the Hydraulic model and optimize the pipe diameters.

(xx) Zero pressure test should be carried out to validate hydraulically discreteness of the DMA.

(xxi) Replace all the leaking House Service Connections (HSC) as maximum leakage occurs at HSCs.

(xxii) Design of the entire transmission main (as per Chapter 6) should be revisited and must be designed properly to validate the required inflow to the tank under consideration.

(xxiii) Strategic control points such as highest, lowest elevation and farthest points should be shown on the hydraulic model and the drawing of operational zone. At these strategic points, SCADA sensors are installed.

(xxiv) Implement SCADA automation for data collection, analytics & predictive analysis for real time monitoring and also install online water quality and pressure monitoring systems in the existing system of the operational Zone/DMA where 24x7 water supply is envisaged.

(xxv) Carry out Financial Feasibility of project which can assess the tariff requirement as well and suggest the expected tariff.

Appendix G (newly added): Retrofitting to refurbish pipe network may be read as a new appendix in inclusion with the existing Guidelines as follows:

Appendix G:
Retrofitting to Refurbish Pipe network

Retrofitting: Retrofitting of pipes is required to refurbish and reengineering of the pipe network in the distribution system.

Case 1: Creation of DMAs

District Metering Areas (DMA)s are the building blocks of any 24x7 water supply scheme. Most of the times the DMAs are needed to be created from the existing pipe network. The process is illustrated in Figure G1.

Figure G1: Retrofitting process

As shown in Figure E1(a) in Appendix E, the operational zone is divided into two DMAs namely, DMA1 (pink) and DMA2(blue). The process of creating DMA involves removing some pipes from the existing network and at the same time adding some pipes. In Figure G1, the pipes denoted by the red colour are proposed to be removed and the pipes shown in cyan (bluish green) colour are required to be added to connect DMA1 (pink colour) to the service tank directly.

Case 2: Hydraulically Discrete Operational Zones

In Table 2.1, it is mentioned that each service reservoir should have one operational zone (OZ) and each OZ to receive water from only single reservoir. This means operational zone should be hydraulically discrete (isolated) from other operational zones. The process of doing this is illustrated in Figure G2.

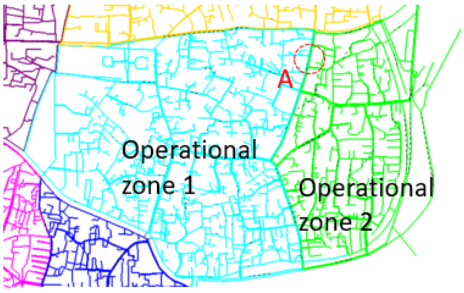


Figure G2(a): Operational zones (OZ)s which are not hydraulically discrete

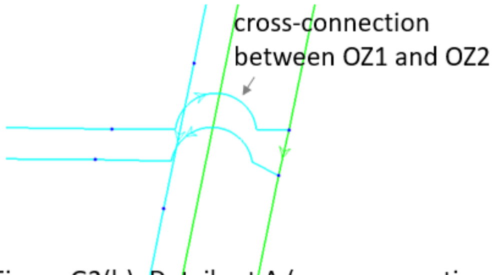


Figure G2(b): Details at A (cross connection between OZ1 and OZ2)

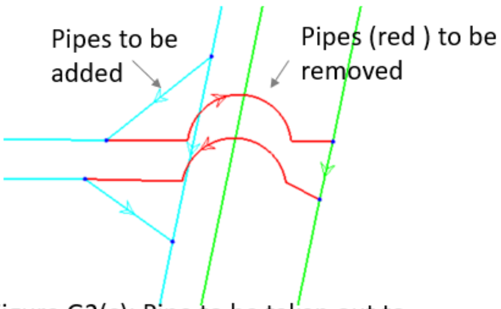


Figure G2(c): Pipe to be taken out to remove cross-connection

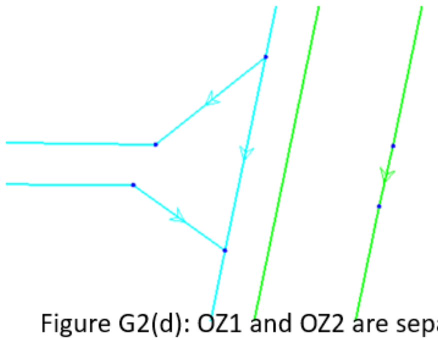


Figure G2(d): OZ1 and OZ2 are separated after removing cross connection

In Figure G2(a), two operational zones (OZ)s are shown as OZ1 in cyan colour and OZ2 in green colour. In existing pipe network there is cross connection between OZ1 and OZ2 as shown in Figure G2(b). To remove the cross connection, the pipes shown in red colour must be taken out and some pipes need to be added as shown in Figure G2 (c). The final hydraulically discrete operational zones, OZ1 and OZ2 are shown in Figure G2(d).

Case 3: Creating Pressure Zones

In the operational zones, the land terrain may be uneven. Due to this, the nodal pressures are high in low lying area and low on high altitude area of the operational zones. Therefore, we need to create pressure zones and accordingly the pipe network is designed. Thus, while designing operational zone, creation of the pressure zones is important task. Retrofitting of pipes is required to separate out pressure zones.

Figure G3(a): Creation of pressure zones

Figure G3(b): Marking pipe network

Using GIS based contours, the raster image of elevations is created (Figure G3(a)). As shown in Figure G3(b), the pipe network of pipes, nodes and tank are marked on the pressure zones. Here the pressure zones are created as raster image of elevations. We need to observe which land polygon covers a part of network and accordingly mark land polygons as shown in Figure G4(a).

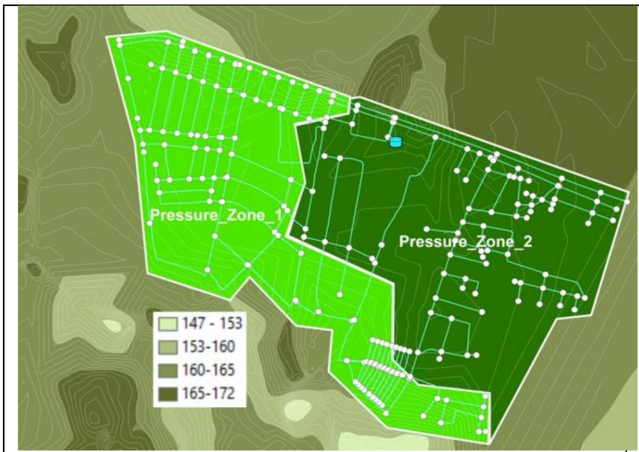


Figure G4(a): Land polygon covering a part of network

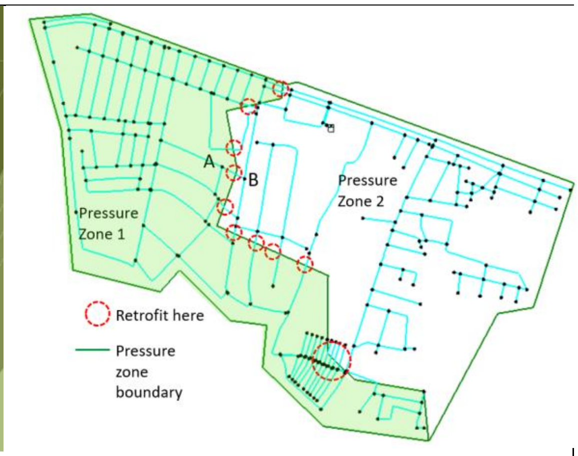


Figure G4(b): Retrofitting required to separate out pipe from pr. zones

There are number of cross connections of pipes shown under red marked circles in Figure G4(b). For separating the pressure zones, it is necessary to remove these cross connections. One such typical cross connection of pipes between the points A and B is shown in Figure G5(a). In order to remove this cross connection between A and B, it is required to cut the pipe (shown in red) between the points A’ and B’ (Figure G5(b)) and then placing end caps at A’ and B’. Thus, after retrofitting the cross connection is removed and the pipes in pressure zones 1 and 2 are separated. The summarised process is shown in Figure G6.

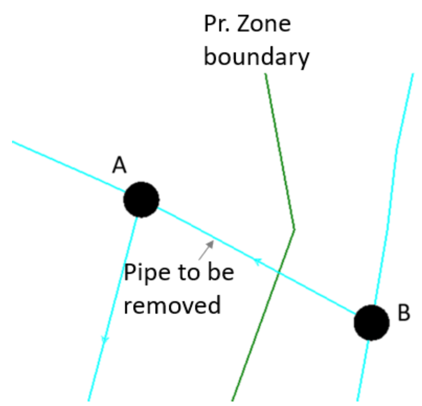


Figure G5(a): Pipe between points A and B as shown in Figure G4(b)

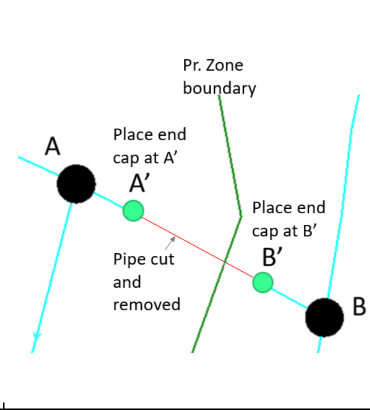


Figure G5(b): Placing end caps at A' and B' and cutting pipe (red colour) between A' and B'

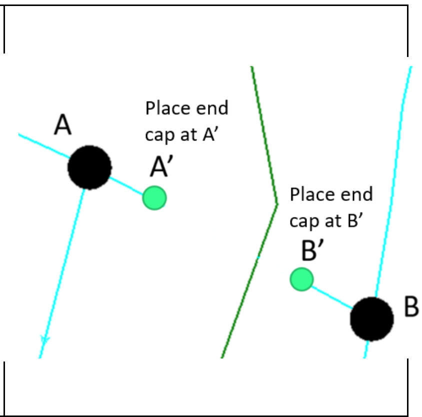


Figure G5(c): After retrofitting, the part of pressure zone 1 is separated from pressure zone 2.

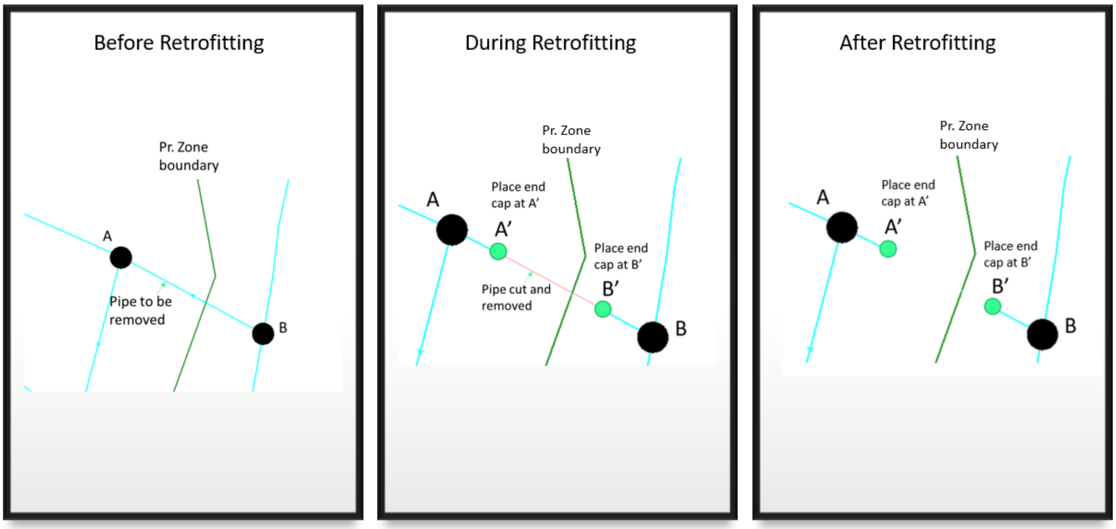


Figure G6: Summarised process of retrofitting

Appendix H (newly added): Direct Feed Networks for 24x7 water supply systems with Smart Control Philosophy using Variable Frequency Device (VFD) may be read as a new appendix in inclusion with the existing Guidelines as follows:

Appendix H:
Direct Feed Networks for 24x7 Water Supply with Smart Control Philosophy using VFD

In most of the developed countries 24x7 water supply is achieved by direct feeding distribution networks using variable frequency drive (VFD) pumps.

Table H1: Comparison of gravity feed and direct feed networks

S. No.	Gravity Feed Network	Direct Feed Network
1	The distribution network is connected to elevated tank or hill service reservoir	The distribution network is connected directly to pump rising mains. Each pump group (rising main) may feed 3-4 District Meter Areas (DMA).
2	Variation in network demand is covered by buffer storage volume in the tank/reservoir.	Variation in network demand to be controlled through pump speed/output.
3	Level based, fixed speed control of pumps	Demand based, pressure control at variable speed of pumps by defining system head to meet required pressure at critical points.
4	High variation in residual pressure at critical point in the network.	Residual pressure in network at critical point is maintained in narrow band.
5	Comparatively High Energy Consumption	Most Energy efficient operation.
6	In case of interrupted supply network, chances of intrusion of outside water during depressurized time, affecting water quality.	Since network is pressurized all the time, water quality is maintained, which gives good control over water borne diseases by avoiding contamination of water in pipelines.

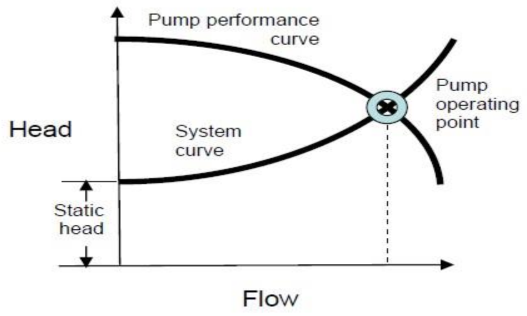
As direct feeding distribution networks using VFD pumps have many advantages like energy saving and assured 24x7 continuous supply with required residual pressures at critical points, it is recommended to adopt this method in Class I & II cities where the distribution network of proper pipe materials are laid and electricity is continuously available through express feeders.

Key points to be considered in pump control philosophy for direct feed network are as follows:

(i) Safe pressurization of water network during pump start after any shutdown work.
(ii) Pumps operation in manufacturer’s recommended operating range or desired efficiency range.
(iii) Quick response to network demand variation.
(iv) Network pressure management- optimizing residual pressure at critical points. Critical points are customer connections at high elevation/low pressure and far end customers in the network with low pressure.
(v) Define service areas (3-5 DMAs) for each pump group (rising main). Generally, one pumping station can have 2-3 pump groups with buffer ground tank/reservoir.

Basic hydraulic features of pumping system:

System Characteristic Curve: The total head, H that the pump delivers includes the elevation head and the head losses incurred in the system. The friction loss and other minor losses in the pipeline depend on the velocity of the water in the pipe, and hence the total head loss can be related to the discharge rate.



System Head can be defined in mathematical form = C1 + (C2 * Flow^2) Where, constant C1 denote elevation head at critical point in the network and constant C2 as head loss coefficient of the network.

Effect of VFD on Pump Performance:

The curves indicating stable pump operation range as recommended by the manufacturer shall be used. It is an envelope formed by Q_{min} - Q_{max} conditions at maximum and minimum speed, where,

- Q_{min} = minimum flow at rated speed (LPS or LPM or m^3/hr)
- Q_{max} = maximum flow at rated speed (LPS or LPM or m^3/hr)
- N_{max} = rated/maximum speed in RPM
- N_{min} = minimum speed in RPS

Pump Operating Point for Complex Network: For a given pump group, there can be a number of system curves for a particular network/rising main. However, a unique system head-capacity (H-Q) curve can be plotted by analysing residual pressure requirements at critical points in the network.

Affinity Laws: If a pump delivers a discharge Q1 at a head H1 when running at speed N1, the corresponding values when the same pump is running at speed N2 are given by the similarity (affinity) laws:

$$\frac{Q_2}{Q_1} = \frac{N_2}{N_1};\quad \frac{H_2}{H_1} = \left(\frac{N_2}{N_1}\right)^2;\quad \frac{P_{i2}}{P_{i1}} = \left(\frac{N_2}{N_1}\right)^3$$

Where, Q = discharge (m3/s, or l/s), H = pump head (m), N = pump rotational speed (rpm) and Pi = power input (HP, or kW).

SMART pump control philosophy:

- Capable of independent and apparently intelligent action,
- Operating with minimal human intervention,
- Independent of external control,
- Controlling the pumps with requisite permissive and protection interlocks,
- Controls include level, flow, pressure, speed, motorized valves, pump run hours, duty/standby configuration, electrical protections etc. fail safe conditions,
- Operating pump within manufacturer's recommended range and desired efficiency criteria.
- PLC control logic operates the pumps as per defined system resistance curve at,
- Active Pressure Set Point = C1 + (C2 x Flow^2)
- PLC logic monitors critical parameters flow, pressure every minute and respond.

While setting up auto operation by control philosophy, following parameters and logical operations shall be considered:

i. System Input data and various permissive/interlock/protection Set Points,
ii. Pump starting sequence with safe pressurization of network,
iii. Adding pump on Maximum Flow conditions with speed reduction ratio.
iv. Throttling on Maximum Flow conditions when standby pump not available,
v. Pump stopping sequence on Minimum Flow conditions,
vi. Recirculation on Minimum Flow (Night Flow) conditions to avoid pump shutdown and supply interruption.

In this way, the pumps always run within Q_{min} to Q_{max} range at various speed. No unstable operation near shut off or in cavitation zone. Control logic shall have flexibility to cover following operations:

- Active Pressure Set points (manual fixed pressure or calculated auto pressure)
- Fail safe procedure (in the event of critical- flow/pressure instruments failure)
- Motorized Valves Control- Suction & Discharge Valves, Rising Main Valves
- Smooth transition from Auto to Manual operation and vice versa.
- Duty-Standby configuration of pumps with Tag-In & Tag-Out options for any maintenance.
- Real time logging of system parameters on timely basis- as a Logbook Record.
- Archiving of data at least for one year for condition monitoring, assessment and system analysis.
- Displaying system performance data- water balance, energy balance and key indicators.
- Trends and alarms for variable system parameters.

Some of the important KPIs for 24x7 water supply system include:

(i) Water Distribution Reliability (24 Hrs)- 100% [(Total pumping hours- hours interruption)/(Total pumping hours)] x 100%
(ii) Water Transmission Availability (hrs.)- 99.9% [(Total Plant Capacity- Planned Outages)/ (Total Plant Capacity)] x 100%
(iii) Water Quality Compliance- Overall 98%, (Biological 98%, Chemical 98%, Physical 98%)
(iv) Water Network Loss – Real loss 6%, NRW target 20%
(v) Average Water Complaint Response Time- 2 Hrs
(vi) Average Water Complaint Resolution Time- 6 Hrs

Smart Pump Control Benefits:

1. The rate of leakage in water distribution network is a function of the pressure. There is a physical relationship between leakage flow rate and network pressure. Higher or lower the pressure, the higher or lower the leakage. Utilities need to balance the requirements. If the network pressure is low there will be higher number of customer's complaint. If higher than sufficient pressure is maintained then losses through leakages increases. Also pressure level and pressure cycling strongly influence burst frequency. Pressure Management is therefore important for the water supply network. Smart pump control philosophy help reduce NRW and breakdowns due to low fluctuations in network pressure. NRW is non-revenue water which include unbilled authorized consumption and water (apparent & real) losses.
2. Better control over the process operation due to minimum human interference.
3. Intelligent system, reduces the risk when handling shutdown works, any branch isolation, would reduce the rising main pressure automatically as affected customers are isolated (demand reduced and calculated auto pressure also reduces). It provide effective & safe normalization of network supply once the shutdown work is completed.
4. Facilitates the benchmarking for better system performance. We can set the operation range (Q_{min}, Q_{max}) as per desired efficiencies based on iso-efficiency curves and system shall work accordingly.
5. Improve MTBF as the pumps operate within stable operation range.
6. System can monitor & control overall system Energy Performance on real time basis (KWH/100 M^3/m head).

Remarks:

Smart Pump Control Philosophy for direct feed networks bring tremendous opportunity for water utilities to realize significant financial savings in O&M of the system due to reduction in pumping head, mitigating water quality issues as network is pressurized all the time, effective NRW management, energy conservation and, reduction in Life

Cycle Cost. Smart Pump Control Philosophy for direct feed networks also support the water loss minimization due to optimized network pressure & improvement in water use efficiency, and reducing the energy demand effectively.

Buffer Tank/ Reservoir Requirements: Ground/ Underground storage capacity should be minimum of (i) 33.33% of average daily demand of intermediate stage or ultimate stage (i.e., 8 hrs storage), for the Operational Zone/DMAs feeding from the reservoirs, which shall be equivalent to 3.2 hrs storage at peak flow (considering peak factor of 2.5) or(ii) capacity computed by mass balance exercise. The capacity for intermediate stage or ultimate stage may be decided based on the availability of the land. This will ensure system reliability without impacting upstream transmission pumps operation or overflow of reservoir, in case of power failure for distribution pumps. Control system shall regulate the operation of all pumps accordingly.

Booster Pump Automation: Wherever ESR is having less pressure head to meet the residual pressure requirements of 21m at critical points, booster pumps can be installed with one bypass arrangement - pipe connecting suction and discharge header with check valve (NRV). This arrangement will protect distribution pipeline from pressure surges or emptying of line. In case of power failure, NRV will open and with available suction head, distribution network will remain pressurised. Once booster pump starts, high discharge pressure will close the NRV. Pump control philosophy shall be implemented as elaborated in this article above to ensure stable operation of pumps within recommended operating range.

DMA is Profusely Leaking: One VFD pump installation serves one operational zones with 3 to 4 DMAs. If it happens that out of the DMAS, one DMA is profusely leaking. In such case the residual pressure can be controlled either by tapering the PRV or the throttling valve.

Pump Sizing and Selection: Pump head calculations should be based on hydraulic modelling of the distribution network for peak flow and residual pressure requirements at critical points for forecasted demand over a period of 15 years. Pump sizing shall be based on the peak flow and available suction head & required discharge pressure to maintain residual pressure at critical point.

Water Utility Service and Customer's Obligations: For effective implementation of 24/7 potable water supply in efficient and cost-effective way-

A) Water Utility to ensure 24x7 potable water supply by building systems with prudent engineering design practice and maintaining high reliability of the system.
B) Water Utility to ensure required pressure and water quality at the customer's end all the time. Water Utility's responsibility shall be limited up to customer's metering point.
C) Customer shall be responsible to maintain proper hygiene in internal piping,

plumbing and their storage at household level. As communities still believe in local household storage for potable water. In case of receiving direct tap water from the Utility, the piping network should not have any interconnection with any other water source to avoid any contamination & back flow to the distribution network.

D) In case of high-rise building, customers must have leak proof 24 hrs storage tank at ground level. All internal piping shall comply with plumbing code for potable water, reuse water, firefighting systems, etc.

Reference: Technical Paper on "Energy Conservation Opportunities in Direct Feed Networks for 24/7 Water Supply with Smart Control Philosophy using VFD", by Er. Dipak D. Dahake published in IWWA Technical Proceedings and presented during 55th IWWA Annual Convention 2023 on the theme, Sustainable Management of Water & Sanitation: Availability for all.