Introduction to Treated Water Storage

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Credit: 3 PDH

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<u>CONTENTS</u>

CHAPTER 1
GENERAL

1.1 PURPOSE AND SCOPE. This course provides an introduction to design criteria for treated water storage requirements at facilities, gives typical design analyses for elevated tanks, standpipes, and reservoirs, and provides guidance on the procedures to be followed in selecting sites for such storage works. The course covers requirements for treated water storage in the distribution system, but not the storage requirements for raw water supplies or fire deluge systems.

1.2 APPLICABILITY. These instructions are applicable to a variety of planning and designing projects requiring treated water storage facilities at fixed developments.

1.3 REFERENCES. Appendix A contains a list of references used in this course.

1.4 OBJECTIVES OF STORAGE.

1.4.1 FLOW REQUIREMENTS. Storage should meet peak flow requirements, equalize system pressures, and provide emergency water supply. The water supply system must provide flows of water sufficient in quantity to meet all points of demand in the distribution system. To do so, the source must produce the required quantity and quality, pressure levels within the distribution system must be high enough to provide suitable pressure, and water distribution mains must be large enough to carry these flows. It is usually inefficient and uneconomical to construct the treatment plant and pumping stations sufficiently large to meet the largest anticipated water demands. A water treatment plant is less efficient if flow rates through the plant are rapidly varied. Water storage facilities are constructed within a distribution network to meet the peak flow requirements exerted on the system and to provide emergency storage.

1.4.2 COST. At times it is desirable to know the cost of constructing water storage for fire protection. In such cases only the actual fire flow for the fire period will be used in

establishing the proportionate share of the total cost of storage. Cost of that portion of the storage required for concurrent domestic, industrial, or special demands that cannot be curtailed during the fire period will not be charged to fire protection.

1.4.3 MEETING PEAK FLOW REQUIREMENTS. Water supply systems must be designed to satisfy maximum anticipated water demands. The peak demands usually occur on hot, dry, summer days when larger than normal amounts of water are used for watering lawns and washing vehicles and equipment. In addition, most industrial processes, especially those requiring supplies of cooling water, experience greater evaporation on hot days, thus requiring more water. The water treatment plant can operate at a relatively uniform rate throughout the day of maximum demand if enough storage is available to handle variations in water use. The necessary storage can be provided in elevated ground, or a combination of both types of storage.

1.4.4 DISTRIBUTION SYSTEM PRESSURES.

1.4.4.1 SYSTEM PRESSURE REQUIREMENTS.

- Minimum pressures. Water distribution system, including pumping facilities and storage tanks or reservoirs, should be designed so that water pressures of at least 280 kPa (40 psi) at ground level will be maintained at all points in the system, including the highest ground elevations in the service area. Minimum pressures of 210 kPa (30 psi), under peak domestic flow conditions, can be tolerated in small areas as long as all peak flow requirements can be satisfied. During firefighting flows, water pressures should not fall below 140 kPa (20 psi) at the hydrants, in new systems. This requirement does not constitute justification or changing existing storage facilities solely for the purpose of increasing residual pressures to 140 kPa (20 psi). Refer to TM 5-813-6/AFM 88-10, Vol. 6 for additional guidance on minimum residual pressures for fire flow.

- Maximum pressure. Maximum water pressures in distribution mains and service lines should not normally exceed 520 kPa (75 psi)at ground elevation. Static pressures up to 670 kPa (100 psi) can be tolerated in distribution systems in small, low-lying areas. Higher pressures require pressure reducing valves on feeder mains or individual service lines to restrict maximum service pressures to 520 kPa (75 psi).

- Multiple pressure levels. If an extensive area has pressures higher than 520 kPa (75 psi) or lower than 280 kPa (40 psi) under a single pressure level configuration, it may be appropriate to divide the system into two or more separate areas, each having different pressure levels. Within each level, pressures within the distribution system should range from 280 to 520 kPa (40 to 75 psi) at ground elevation.

1.4.4.2 PRESSURE DISTRIBUTION WITH ELEVATED STORAGE.

- Elevated storage within the distribution system permits distribution pumps at the treatment plant to operate at uniform rates.

- The usefulness of elevated storage is shown in Figure 1-1. The system illustrated in Figure 1-1 (A) (without elevated storage) requires storage at the plant sufficient to provide for system demand rates in excess of the plant production rate, assuming the plant is operated at a uniform rate. The pump station forces water into the service main, through which it is carried to three load areas: A, B, and C. Since all loads on the system are met without the use of elevated storage, the pump station must be capable of supplying the peak rates of water use to Areas A, B, and C, simultaneously, while maintaining the water pressure to Area C at a sufficient level. The minimum recommended pressure in the distribution system under peak nonemergency flow conditions is 280 kPa (40 psi). Figure l-l (B) assumes the construction of an elevated storage tank on the service main between Areas B and C, with peak loads in Area C and part of the peak load in

Area B being satisfied from this tank. The elevation of the tank ensures adequate pressures within the system. The storage in the tank is replenished when water demands are low and the pump station can fill the tank while still meeting all flow and pressure requirements in the system. The Figure 1-1 (B) arrangement reduces required capacity of the distribution pumps.

- Most elevated storage tanks "float" on the distribution system. That is, the elevated tank is hydraulically connected to the distribution system, and the volume of water in the tank tends to maintain system pressures at a uniform level. When water use is high and pumping facilities cannot maintain adequate pressures, water is discharged from elevated tanks. Conversely, when water use is low, the pumps, which operate within a reasonably uniform head-capacity range, supply excess water to the system and the elevated storage is refilled.

1.4.5 PROVISION OF EMERGENCY WATER SUPPLIES.

1.4.5.1 FIREFIGHTING FLOWS. This demand can occur at any time, but may well coincide with other large water demands on the system.   Storage and distribution facilities will include capacity for required firefighting flows at adequate pressures at any point of the installation.

1.4.5.2 OTHER EMERGENCIES. Water storage must provide an emergency supply of water in the event the water treatment plant, distribution pumps, or a principal transmission main is out of service. The amount of emergency storage required depends on the reliability of the system and the extent of other safeguards incorporated into the system, i.e., finished water interconnections with a municipality (for either normal or emergency use).
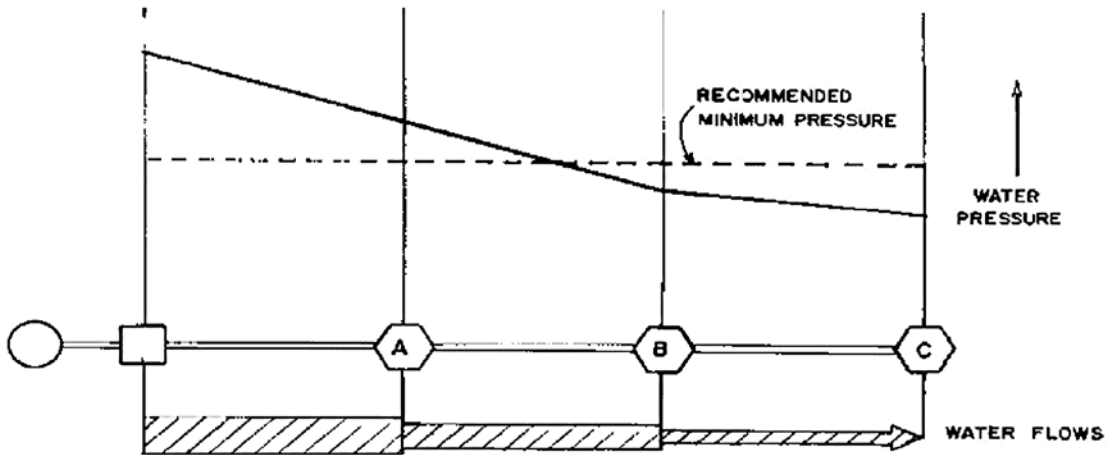
(A) WATER FLOWS AND PRESSURES WITHOUT ELEVATED STORAGE
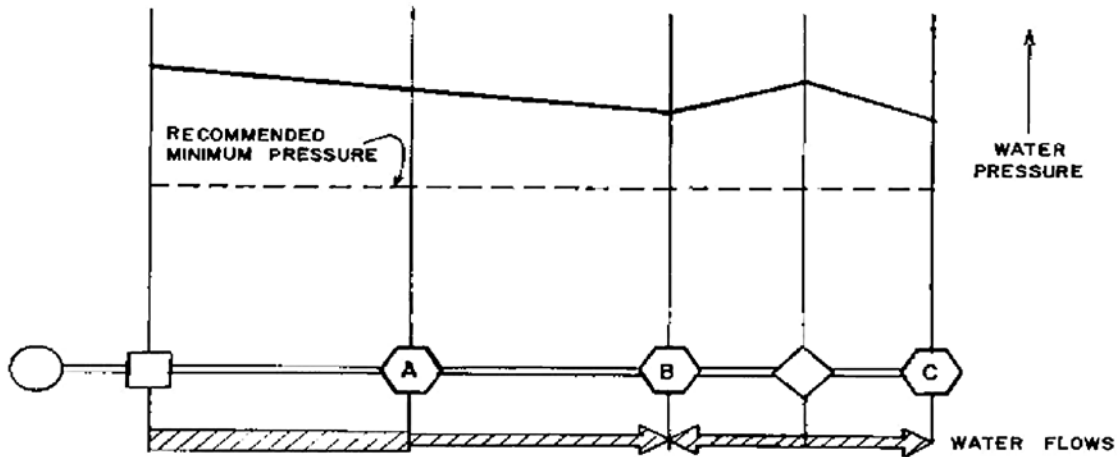
(B) WATER FLOWS AND PRESSURES WITH ELEVATED STORAGE

LEGEND

○ WATER TREATMENT PLANT
□ PUMP STATION AND PUMPED STORAGE
◎ DEMAND LOAD CENTER
◇ ELEVATED STORAGE

EFFECTS OF ELEVATED STORAGE

Figure 1-1

Effects of Elevated Storage

CHAPTER 2
TYPES OF STORAGE

2.1 GENERAL. Required storage capacity may be met by use of elevated or ground storage. Elevated storage, feeds the water distribution system by gravity flow. Storage which must be pumped into the system is generally in ground storage tanks. Clearwell storage, which is usually part of a water treatment plant, is not included in computing storage unless sufficient firm pumping capacity is provided to assure that the storage can be utilized under emergency conditions, and then only to the extent of storage in excess of the 24-hour requirements of the treatment plant. Clearwell storage is used to supply peak water demand rates in excess of the production rate, and to provide a reservoir for plant use, filter backwash supply, and water supply to the system for short periods when plant production is stopped because of failure or replacement of some component or unit of treatment.

2.2 GROUND STORAGE.

2.2.1 GENERAL. Ground storage is usually located remote from the treatment plant but within the distribution system. Ground storage is used to reduce treatment plant peak production rates and also as a source of supply for pumping to a higher pressure level. Such storage for pumping is common in distribution systems covering a large area, because the outlying service areas are beyond the range of the primary pumping facilities.

2.2.2 TYPE. Ground storage tanks or reservoirs, below ground, partially below ground, or constructed above ground level in the distribution system, may be accompanied by pump stations if not built at elevations providing the required system pressure by gravity. However, if the terrain permits, this design location of ground tanks at elevation sufficient for gravity flow is preferred. Reservoirs are the most common type of water storage structure and are categorized as being ground supported with a flat bottom and a height no greater than its diameter. Concrete reservoirs are generally built no deeper

than 6-7.5 meters (20-25 feet) below ground surface. If rock is present, it is usually economical to construct the storage facility above the rock level. In a single pressure level system, ground storage tanks should be located in the areas having the lowest system pressures during periods of high water use. In multiple pressure level systems, ground storage tanks are usually located at the interface between pressure zones with water from the lower pressure zones filling the tanks and being passed to higher pressure zones through adjacent pump stations.

2.3 ELEVATED STORAGE

2.3.1 GENERAL. Elevated storage is provided within distribution system to supply peak demand rates and equalize system pressures. In general, elevated storage is more effective and economical than ground storage because of the reduced pumping requirements, and the storage can also serve as a source of emergency supply since system pressure requirements can still be met temporarily when pumps are out of service.

2.3.2 TYPE. The most common types of elevated storage are elevated steel tanks and standpipes. An example of a conventional elevated steel tank is given in Figure 2-1. In recent years, elevated tanks supported by single pedestals, such as shown in Figure 2-2, have been constructed where aesthetic considerations are an important part of the design process. (See *American Water Works Association AWWA D100 - Appendix A*).

2.3.3 STANDPIPE. A standpipe is a tall cylindrical tank normally constructed of steel or reinforced concrete. It is a ground supported, flat bottom, cylindrical tank with heights greater than its diameter. Only the portion of the storage volume of a standpipe that meets the requirements below is considered useful storage for pressure equalization purposes. The lower portion of the storage acts to support the useful storage, to provide a source of emergency water supply, and must be pumped into the distribution system.

2.3.4 ELEVATED STORAGE. Elevated storage tanks should be located in the areas having the lowest system pressures during intervals of high water use to be effective in maintaining adequate system pressures and flows during periods of peak water demand. They are those of greatest water demand or those farthest from pump stations. Elevated tanks are generally located at some distance from the pump station(s) serving a distribution pressure level, but not outside the boundaries of the service area, unless the facility can be placed on a nearby hill. Additional considerations for siting of elevated storage are conditions of terrain, suitability of subsurface soil and/or rock for foundation purposes, and hazards to low-flying aircraft. Elevated tanks are built on the highest available ground, up to static pressures of 520 kPa (75 psi) in the system, so as to minimize the required construction cost and heights.
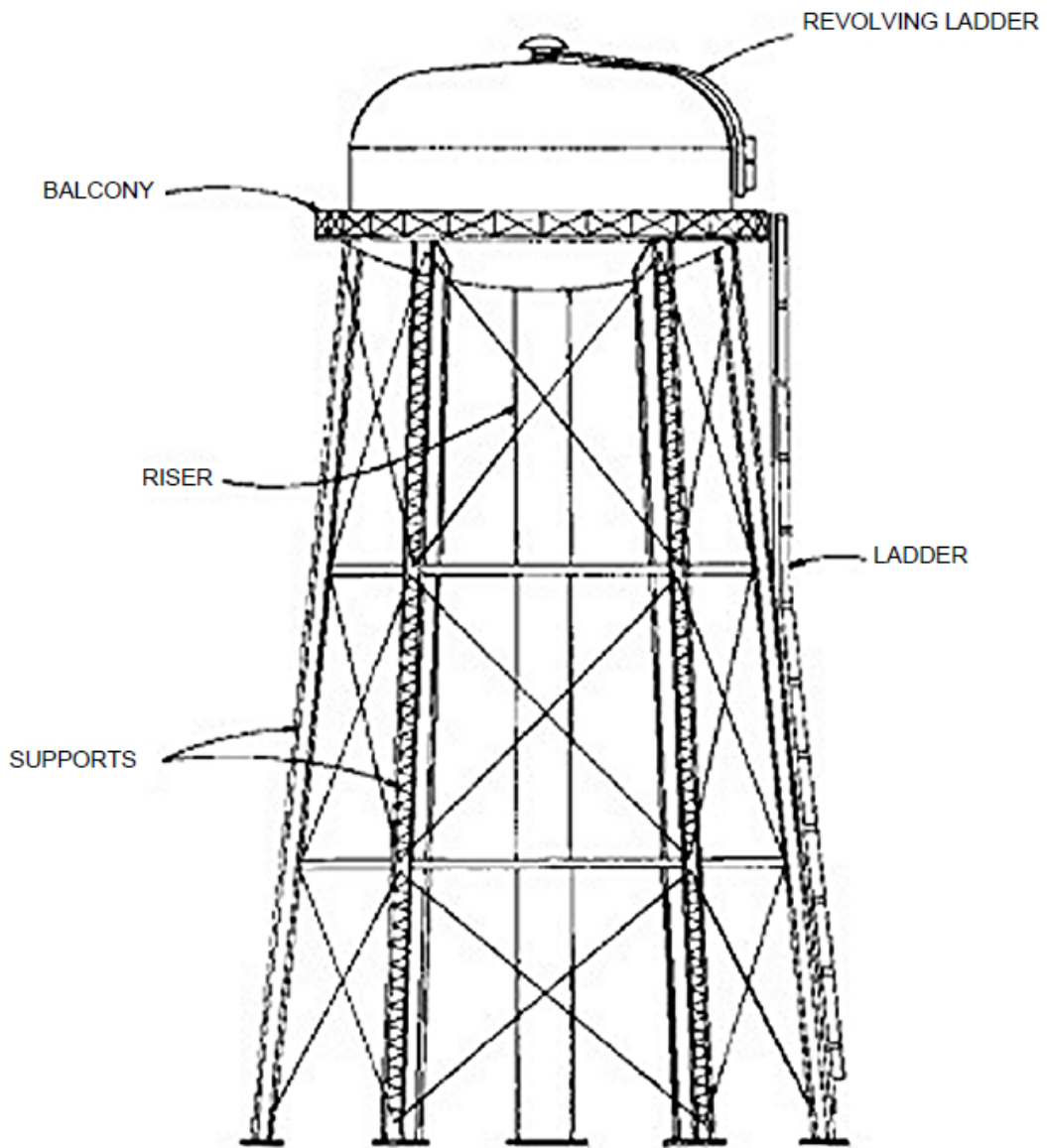
Figure 2-1

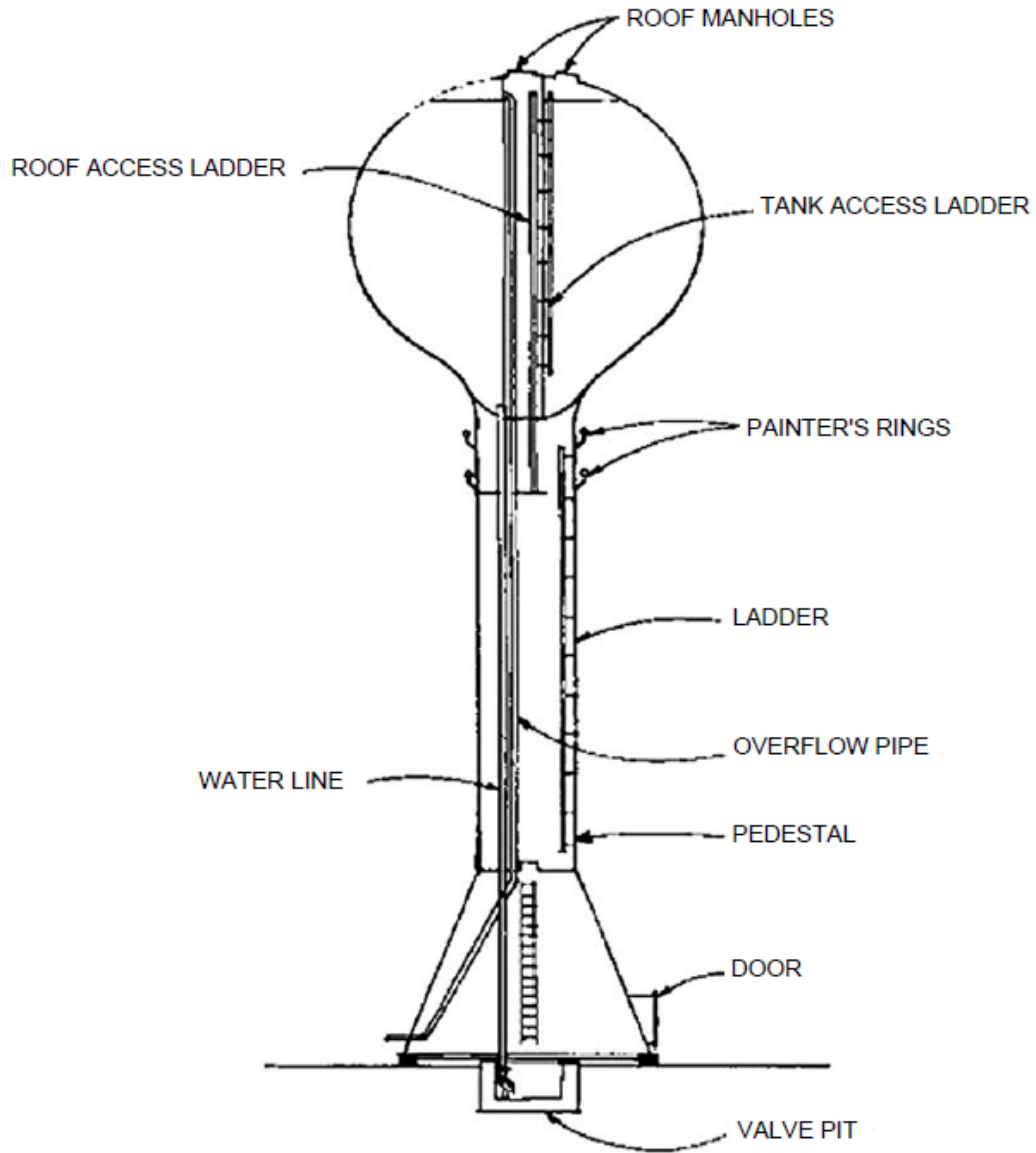Elevated storage tank (alternative design)

Figure 2-2

Elevated storage tank (alternative design).

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CHAPTER 3

DETERMINATION OF CAPACITY REQUIREMENTS

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3.1   TOTAL STORAGE REQUIREMENTS. The amount of water storage provided should generally conform to the requirements set forth herein.

3.1.1 ALL INSTALLATIONS. In general, total storage capacity, including elevated and ground storage, will be provided in an amount not less than the greatest of the following items.

3.1.1.1 ITEM 1. Fifty percent of the average total daily domestic requirements plus all industrial requirements. This will provide minimum operational storage needed to balance average daily peak demands on the system and to provide an emergency supply to accommodate essential water needs during minor supply outages of up to a one-day duration. For the purposes of this item, essential water needs do not include the fire demand.

3.1.1.2 ITEM 2: THE FIRE DEMAND. The fire demand is the required fire flow needed to fight a fire in the facility (including water required to support fire suppression systems) which constitutes the largest requirement for any facility served by the water supply system; plus 50 percent of the average domestic demand rate plus any industrial or other demand that cannot be reduced during a fire period. Large and diverse projects where the fire flow is a major consideration require the services and review of a qualified fire protection engineer.

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NOTE

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The fire demand quantity must be maintained in storage for fire protection at all times except following a fire fighting operation when the fire demand quantity would be depleted. If depleted, the water system must be self-replenishing and capable of refilling the required volume within 48 hours during normal operation and within 24 hours when normal consumption is curtailed. It is recognized that during daily periods of peak consumption due to seasonal demands, the amount

of water in storage will be less than full storage capacity; however, conservation methods will be instituted to prevent drawdown of water in storage below the fire demand quantity. Water storage greater than the amount determined by the largest of Items 1, 2, or 3 may be required because of appropriate adjustments for emergency water quantity or other applicable factors; however, this must be substantiated by actual data on a repeated annual basis documenting the low storage levels occurring during normal peak demand.

3.1.1.3 ITEM 3: The sum of Items 1 and 2 above, that is, the sum of fifty percent of the average total daily domestic requirements, all industrial requirements for an average day which cannot be shut off during emergency conditions, and the required fire demand. The sum of the above items will be reduced by the amount of water available in 24 hours under emergency conditions. This will provide maximum storage where emergency water supply is a minimum over a 24-hour period or a supply main outage would significantly affect overall supply conditions. The most economical alternative for meeting the water storage requirements will be selected in all cases. Installation of additional emergency pumping facilities, additional water supply connections, drilling additional wells or other modifications to the water system, which will be more cost effective than increasing storage capacity, will be developed.

3.1.2 SPECIAL CONSIDERATIONS. The amount of storage required for plant and special projects will be based on industrial, domestic, and fire-protection requirements. Each project will be considered on the basis of specific need. Hospital storage facilities will be designed in accordance with the latest edition of the Joint Commission Accreditation Manual for Hospitals, American Hospital Association.

3.1.3 AMOUNT OF WATER AVAILABLE UNDER EMERGENCY CONDITIONS.

3.1.3.1 The amount of water available under emergency conditions is considered to be that available from auxiliary-powered pumps during electric-current outage, from electric-motor-driven pumps with the largest pump out of service, from one or more

supply mains with the main of greatest capacity out of service, or from the water-treatment plant with one filter out of service. Normally the capacity of the clearwell storage at the treatment plant will not be considered part of the required storage.

3.1.3.2 Where the water supply is obtained from wells, all of which are equipped with standby power and located within the distribution system, the emergency supply will be considered as the quantity available from all but one of the wells. Where one well has a capacity greater than the others, that one will be assumed out of service. Where only 50 percent of the wells have standby power, the emergency supply will be considered as the quantity available from the wells having standby power.

3.1.3.3 Where the project is supplied from a dependable existing source, such as a municipal system with adequate storage and standby facilities, through supply lines not subject to damage by floods, high pressure, or other unusual conditions, the amount of water available under emergency conditions is that obtainable with the largest connection inoperative.

3.1.3.4 Where the supply is delivered through a single supply main, the maximum amount of storage as determined above will be provided.

3.1.3.5 Where the peak demand for water is available at adequate residual pressure through two or more lines while the line having the greatest capacity is out of service, no storage will be required.

3.1.3.6 Where the peak demand for water is available through two or more lines but is not available if the line having the greatest capacity is out of service, storage will be required. The quantity of water available under emergency conditions with the line of greatest capacity out of service will be considered in calculating the amount of storage required.

3.1.4 IRRIGATION REQUIREMENTS. Where irrigation requirements are justified in arid or semi-arid regions, such irrigation quantities will be included as an industrial requirement and not as a domestic requirement. Water requirements may be increased above those indicated if substantiated by a local or regional Soil Conservation Service or recognized local authority as the minimum rate to sustain lawn-type turf.

3.2 ELEVATED STORAGE CAPACITY. The total elevated storage capacity at all developments except plant and special projects, should not be less than the amount determined above nor less than 50 percent of the total required storage, unless special conditions prevail which would negate the need for such storage. For projects with design populations of 10,000 or less, consideration will be given to providing all elevated storage where the storage will result in an economical and reliable system. For projects such as storage depots or aircraft hangers with deluge sprinkler systems, ground storage reservoirs with booster pumps will generally be the more economical method of supplying large volumes of water for fire protection. Elevated tanks will normally be provided for initial sprinkler demand in storage warehouses. Water storage can be most economically provided by constructing ground storage reservoirs on high ground. However, in the absence of suitable terrain, elevated tanks will be required.

3.3 ECONOMIC ANALYSES

3.3.1 GENERAL. Economic analyses of storage requirements could guide decisions on the implementing or postponing of expenditures for new transmission mains, the constructing of booster pumping facilities to increase transmission main capacities instead of adding new mains, the increasing of the quantity of storage within a distribution system, and the providing of elevated storage or ground storage with booster pumping facilities.

3.3.2 DISTRIBUTION STORAGE. Distribution storage is intended to meet peak flow requirements or emergency needs, maintain system pressures, and thus reduce the required capacities of the treatment plant and pump stations. The design of storage

facilities will be determined by feasibility studies which take into account all engineering, economic, energy, and environmental factors.

CHAPTER 4

DESIGN AND CONSTRUCTION OF WATER STORAGE FACILITIES

4.1 CONSTRUCTION MATERIALS.

4.1.1 CONCRETE.

4.1.1.1 GENERAL. Reinforced concrete is popular for construction of reservoirs and standpipes because it produces structures with long service lives and which require little maintenance. Such reservoirs and tanks can be below or partially below ground with the above ground portion architecturally enhanced if needed by the setting.

4.1.1.2 PRESTRESSED CONCRETE TANKS. Standards for the design and construction of wire-wound circular prestressed-concrete water tanks are provided by AWWA D110. Such tanks can be constructed of cast-in-place concrete, shotcrete, or precast concrete. An interior, vertically reinforced concrete wall encases a mechanically lock seamed steel diaphragm, which provides water-tight containment. The wall and diaphragm is covered with shotcrete and continuously stressed wire is wrapped in layers around the structure as the shotcrete is applied. A painted or decorative coating can be applied to the exterior.

4.1.2 STEEL.

4.1.2.1 GENERAL. Steel reservoirs and standpipes weigh about one-eighth as much as concrete tanks and are generally more economical for remote sites where it is difficult to transport materials. The lower weight will also reduce the foundation requirements.

4.1.2.2 WELDED TANKS. All elevated steel tanks and many standpipes and reservoirs are of welded steel construction, allowing them to be dismantled, moved, and reconstructed. Welded tanks have been used since the 1930's for water storage and

have completely replaced riveted construction. Standards for design and construction of welded water tanks, with capacities of 19,000 L to 11 ML (5,000 gal to 3 Mgal), are provided in AWWA D100.

4.1.2.3 BOLTED TANKS. Factory-coated bolted steel water tanks became popular in the 1970's for standpipes and reservoirs. They utilize steel panels (of lighter gauge than welded tanks) that are bolted together onsite using gaskets or sealants for sealing the joints. Compared to welded tanks, they are easy to dismantle and relocate. Standard capacities range from 15,000 L to 6.8 ML (4,000 gal to 2.5 Mgal). Standards for design and construction of bolted steel tanks are provided in AWWA D103.

4.1.3 COMPOSITE. Another type of elevated tank is the composite tank which consists of a welded steel tank supported by a reinforced concrete pedestal of tower. Design and construction guidance are provided in Steel Plate Fabricators Guideline Specification for Composite Elevated Water Tanks.

4.2 ROOFS AND COVERS. All treated water tanks and reservoirs must be covered to prevent contamination by dust, birds, leaves, and insects. These covers will be, insofar as possible, watertight at all locations except for vent openings. Special attention should be directed toward making all doors and manholes watertight. Vent openings must be protected to prevent the entry of birds and insects; and vent screens should be kept free of ice or debris so that air can enter or leave the storage area as temperature and water levels vary. All overflows or other drain lines must be designed so as to eliminate the possibility of flood waters or other contamination coming in contact with the treated water. Covers also protect the stored water from sunlight, thus inhibiting the growth of algae. Further prevention of algae growth or bacterial contamination, due to the depletion of the chlorine residual, can be obtained by maintaining sufficient flow through the tank or reservoir so that stored water does not become stagnant. Minimal flows through the system also help to prevent ice buildup during cold periods.

4.2.1 RESERVOIRS AND STANDPIPES. In public and private communities, significant emphasis has been placed on making water storage facilities attractive so as not to distract from the appearance of the community. This has lead to the development of a variety of roof designs. On military sites, the most economical functional roof will be used except where the setting requires a more aesthetically pleasing design. A column-and-rafter supported steel roof, with columns supported by footings rather than the tank walls, is generally the most economical type for a reservoir and can be used on a standpipe less than 50 feet in height. Self-supporting (supported by the tank) cone roofs have proven to be inexpensive and quite functional for small diameter reservoirs and standpipes. Roofs supported by the tank are generally dome or umbrella-shaped steel roofs and provide a smooth appearance. Roof styles for welded steel tanks include conical, umbrella, dome, and ellipsoidal designs. Bolted steel tanks commonly have conical steel roofs or aluminum domes. Aluminum domes have also been used for welded steel and concrete tanks and reservoirs. Advantages that aluminum may have over other roof materials (depending on the individual situation) are improved corrosion resistance, light weight, lower costs, easier erection, enhanced aesthetics, and less maintenance. Dead weights of metal roofs average 140 N/m 2 (3 lbs/ft2) or less for aluminum, 180 N/m2 (3.8 lbs/ft2) for bolted steel, and 360 N/m 2 (7.6 lbs/ft2) for welded steel. Cast-in-place and precast concrete (dome and flat) roofs have also been provided for concrete tanks whereby flat concrete roofs are used for buried tanks when the ground above is needed for other uses.

4.2.2 ELEVATED TANKS. Roofs for elevated tanks are generally a self-supporting integral part of the tank. Self-supporting dome and umbrella designs have been used for smaller tanks.

4.3 ALTITUDE VALVES. All storage tanks will be provided with altitude valves to prevent overflows. These altitude valves will be installed in concrete pits having provision for draining either by gravity or pumping. Drains will not be connected to sanitary sewers. Every precaution will be taken to prevent the collection of water from any source in valve pits.

4.4 INSTRUMENTATION AND CONTROL. Storage measurements are used for monitoring, inventory, and system controls. Elevated and ground storage measurements will be made by pressure sensitive instruments directly connected by static pressure lines at points of no flow. Underground storage measurements will be made by air bubbler back pressure sensitive instruments or by float actuated instruments. The direct pressure measurements of elevated tanks will be suppressed to readout only the water depth in the elevated bowl. High and low level pressure sensitive switches will be used for alarm status monitoring and for pump cut-off controls. Intermediate level switches, pressure or float actuated, will be used for normal pump controls. Metering, monitoring, and pump control requirements at some point remote from storage must use level telemetry instruments. Telemetering over local direct wire communications facilities will use 15-second time duration or impulse duration telemetering equipment. Telemetering over leased telephone lines often requires the introduction of a tone transmitter and receiver keyed by the time-impulse telemetering equipment. High storage level will initiate the shutdown of supply pumping units and actuation of an overflow alarm in that order. Low storage level will initiate startup of supply pumping or well pumping units or distribution pumping unit shutdown.

4.5 DISINFECTION. Potable water storage facilities, associated piping, and ancillary equipment must be disinfected before use. Disinfection will be accomplished following procedures and requirements of AWWA C652. In no event will any of the above equipment or facilities be placed in service prior to verification by the supporting medical authority, using bacteriological tests, that disinfection has been accomplished.

4.6 DESIGN ANALYSES. The design analyses will set forth the basis by which storage capacities and locations have been determined. Except where standard specifications for tanks or towers are used, the analyses will show the method by which the structural adequacy of the unit has been determined.

4.7 CORROSION CONTROL.

4.7.1 CORROSION PROCESS. Corrosion is the natural deterioration and loss of material due to a chemical or electrochemical reaction with its environment. Electrons in metals are loosely bound to their atoms and easily removed in the presence of an electrolyte such as water. The basic elements of corrosion are an anode (the corroding metal), a cathode (a non-corroding metal), an electrolyte (a solution such as water which conducts electricity), and a closure path for the current connecting the anode and cathode. In corrosion, galvanic cells are formed in which certain areas become anodes and others cathodes. Electric current flows through the electrolyte and metal as the anode is corroded. Corrosion does not occur if any of these elements are missing. To prevent corrosion, all steel water structures shall have a protective coating system, which prevents the current from flowing between the metal and electrolyte, and an impressed-current cathodic protection system.

4.7.2 CATHODIC PROTECTION. Coating systems cannot be applied completely without flaws. Cathodic protection systems arrest corrosion at such flaws by reversing the electric current and turning the metal to be protected into the cathode. In an impressed-current system, an electrical current from an outside source flows into anodes (located inside the tank) through the water and into the structure.

4.8 COATING SYSTEMS.

4.8.1 GENERAL. The paint and coating systems industry changes rapidly with new products regularly becoming available. It is also impacted by the restricted use or ban of many products due to changing EPA, OSHA, or health laws and regulations. OSHA has set highly restrictive limits on the use of products containing lead, chromate, or mercury. When specifying a system, the number and thickness of each coat, primer, surface preparation method, and curing conditions (temperature, time, etc.) must be given.

4.8.2 INTERIOR. Coatings used on interior surfaces of a tank, including that of risers and all other surfaces in contact with the water, must not add taste, odor, toxicity, or impurities to the water; must readily adhere to the tank's surface while continuously submerged; must have a low rate of permeability; and must meet the minimum requirements of NSF Standard 61. For potable water tanks, the systems must also be acceptable to the appropriate regulatory agencies. Several standards are available for use as references. Two of the more popular standards used when painting steel tanks are "Coatings For Potable Water Tank Interiors" by the Steel Structures Painting Council and AWWA D102. Common interior systems include epoxies, vinyl, and coal-tar systems.

4.8.3 EXTERIOR. While the exterior of concrete tanks are generally painted only for aesthetics, steel tanks must be painted or coated to protect the tank. Exterior coating systems must be selected based on local climatic conditions. Alkyd enamel systems are good for rural areas; mild to fairly heavy industrial atmospheres and mild atmospheres. Vinyl, epoxies, urethane, and polyurethane systems are better for moderately severe to the most severe atmospheres, such as seacoasts and corrosive industrial areas. Vinyl paints have the advantage of being very fast drying and should be used in congested areas where overspray could damage property (vinyl paint overspray from elevated tanks will dry before reaching the ground) but fade easily and should be specified only in white or light gray colors. Polyurethanes have widespread application as they retain their color and gloss well, are highly abrasion resistant, and are easy to clean of graffiti. Silicone alkyd systems are also weather resistant, high gloss coatings with good color and gloss retention as well as good resistance to many chemicals. Alkyd and silicone alkyd systems are generally not recommended in locations subject to excessive condensation. Applicable standards include AWWA D102, AWWA D103, and the Steel Structures Painting Council.

4.9 BID DOCUMENTS. Design of large tanks, standpipes and reservoirs, especially prestressed concrete structures and elevated tanks, is complex as it demands a wide range of special and unique knowledge and experience. Subsequently the majority of

the water storage structures may be bid using performance specifications requiring the bidding contractor to prepare detailed designs and specifications. Whether construction drawings and specifications or performance specifications are prepared for bids, the owner is responsible for providing specific information to the contractor. The owner's as well as the engineer's responsibilities are given in the applicable AWWA standards and manuals. The contractor is expected to be aware of AWWA standards and federal laws but the bid document must provide local codes and regulations or more stringent loading criteria (water, snow, wind and live loads). Other information to be incorporated in bid documents include:

- Acceptable types of tanks, tank walls, and roofs
- Borings and geotechnical information needed for design of foundations
- Notification requirements: Whether or not local officials, other than the Contracting Officer's representative, will inspect the disinfection process and/or take water samples for testing

The owner is also responsible for furnishing an adequate supply of potable water at the proper pressure for filling the tank.

APPENDIX A
REFERENCES

American Water Works Association, 6666 West Quincy Ave., Denver, CO, 80235

AWWA D100 Welded Steel Tanks for Water Storage

AWWA D102 Coating Steel Water-Storage Tanks

AWWA D103 Factory Coated Bolted Steel Tanks for Water Storage

AWWA D104 Automatically Controlled, Impressed-Current Cathodic

Protection for the Interior of Steel Water Tanks

AWWA C652 Disinfection or Water Storage Facilities

Joint Commission on Accreditation of Hospitals, 875 N. Michigan Avenue, Chicago, Illinois 60661

Accreditation Manual for Hospitals

NSF International, 3475 Plymouth Road, Ann Arbor, MI 48113-0140

NSF Standard 61 Drinking Water System Components - Health Effects

Steel Plate Fabricators Association, Inc., 2400 South Downing Ave., Westchester, IL 60154.

Guideline Specification for Composite Elevated Water Storage Tanks

APPENDIX B

TYPICAL DESIGN EXAMPLES

B. 1   GENERAL. The following typical design examples illustrate procedures to be followed in the determination of total capacity requirements for representative water storage facilities.

B.2 EXAMPLE NO. 1: COMMUNICATIONS FACILITY; PERMANENT CONSTRUCTION

B.2.1 EFFECTIVE POPULATION.

Nonresident: 400

Resident: 700

Total: 700 + (400 divided by 3) = 833

B.2.2 WATER SOURCE.

Wells available; average yield 9.5 L/s each.

B.2.3 TREATMENT - CHLORINATION.

B.2.4 REQUIRED DAILY DEMAND AND FIRE FLOWS.

Capacity factor: 1.5

Design population: 833 X 1.5 = 1,250

Per capital allowance: 570 L/d

Special demands: None

Required daily demand: 1,250 X 570 = 712,500 L/day, equivalent to a rate of 8.25 L/s.

Firefighting flow: 32 L/s (500 gal/min) for 2 hours

Maximum day demand: 8.25 X 2.5 = 21 L/s.

B.2.5   WELL REQUIREMENTS.

- **TOTAL WELL YIELD:** Assuming 24-hour/day well operation, one well has sufficient yield to meet the required daily demand rate of 8.25 L/s. However, for firm production capability, it is necessary to have two wells, each capable of 8.25 L/s.

- **MINIMUM PUMP REQUIREMENT:** The dependable output of the source of supply, i.e. the two wells, must be equal to, or greater than, the required daily demand. Thus, each well should be equipped with a 8.5 L/s pump. Two reliable sources of electric service should be provided, or one pump should be equipped with both an electric motor and standby internal combustion engine. The size and number of distribution pumps required are related to the type, size, and location of storage facilities. Provisions of elevated storage will reduce the required pump capacity.

B.2.6   STORAGE REQUIREMENT.

ITEM 1: 50 percent of total daily domestic requirements:
712,500 divided by 2 = 356,250 L.

ITEM 2: Fire demand:
(32 + 8.25/2) X 60 X 60 X 2 = 260,000 L.

This item will be reduced by the amount of water available during the period of the fire demand under emergency conditions. The amount available under emergency conditions is the production of one well, so this item becomes 260,000-(8.5 X 2 X 60 X 60) = 198,800 L.

ITEM 3: 50 percent of total daily domestic requirements plus the fire demand minus the production of one well in 24 hours: 356,250 + 260,000 - (8.5 X 24 X 60 X 60) = -118,150 gallons. The largest of the above items, 356,250 L, governs the

total storage requirements. Storage of not less than 400,000 L should be provided. In this case, it is suggested that a 400,000 L elevated tank be provided.

B.2.7   WATER MAIN SIZES. The water distribution system will have mains of adequate size to meet peak domestic demand.

B.3 EXAMPLE NO. 2: PERMANENT DEVELOPMENT.

B.3.1 EFFECTIVE POPULATION.

Nonresident: Negligible

Resident: 20,000

B.3.2 . WATER SOURCE.

Surface supply from river.

B.3.3 TREATMENT.

Coagulation, flocculation, sedimentation, filtration, and chlorination.

B.3.4 REQUIRED DAILY DEMAND AND FIRE FLOWS.

- Capacity factor: 1.15.
- Design population: 20,000 X 1.15 = 23,000
- Per capita allowance: 150 gal/day.
- Special demand: Irrigation of lawns and shrubbery estimated to require as much as 400,000 gal/ day
- Required daily demand: (23,000 X 150) + 400,000 = 3,850,000 gal/day equivalent to a rate of 2,674 gal/min
- Maximum day demand: 2,674 X 2.5 = 6.684 gal/min
- Fire fighting flows:
  - □ Residential: Fire Flow: 1500 gpm Duration: 2 hours = 1500 x 60 x 2 = 180,000 gals

- Warehouse (40,000 ft 2, Type I construction, extra hazard occupancy):
  - 2,800. gal/min for a duration of 3 hours = 2,800 x 60 x 3 = 504,000 gallons
- Hospital (1,500 gal/min for a duration of 2 hours = 1,500 x 60 x 2 = 180,000 gallons
- To meet the required daily demand, a treatment plant with pumping stations and appurtenances having a rated capacity of approximately 4,000,000 gal/day would be provided.

B.3.5 STORAGE REQUIREMENTS.

ITEM 1: 50 percent of total daily domestic requirements =
[(23,000 x 150) + 400,000]/2 = 1,925,000 gallons

ITEM 2: Fire demand = (2,800x60x3) + [(23,000x150x4)/(24x2)] = 719,630 gallons

The irrigation requirement can be eliminated during the fire period, so it is not included in this computation. This item will be reduced by the amount of water available during the period of the fire demand under emergency conditions. It is recommended that a sufficient number of both raw and filtered water pumps be equipped with dual power sources (electric motor-internal combustion engine) or standby internal combustion engines to be capable of supplying at least 50 percent of the required daily demand under emergency conditions. In this case both the raw water and filtered water pumping equipment will be equipped with dual power sources. The storage requirement for fire demands becomes 719,630 - (1,350 X 60 X 3) = 476,630 gallons.

ITEM 3: 50 percent of required daily demand plus fire demand minus the amount of water available in 24 hours under emergency conditions =
1,925,000 + 719,630 - (1,350 X 60 X 24) = 700,630 gallons

The first item governs; storage of about 2,000,000 gallons should be provided. At least 50 percent of the storage should be elevated since the population exceeds 10,000. Two 500,000-gallon elevated tanks would be satisfactory, with the remainder of the required storage provided in a ground storage reservoir.

B.3.6 RAW-WATER PUMPING STATION. Two 2,700 gal/min electric motor driven pumps and a 1,350 gal/min dual drive (electric motor with standby internal combustion engine) pump will be provided.

B.3.7 HIGH-LIFT PUMPING STATION. Pumping facilities, similar to those for raw water pumping station, will be provided.

B.3.8 WATER MAIN SIZES. Water mains will be in accordance with the criteria of industry standards.

B.4 EXAMPLE NO. 3: A MULTIPLE RESIDENTIAL FACILITY. Type 1, Fire resistive construction, unsprinkled facilities, floor area 125,000 sq. ft.

B.4.1 Effective population. 3,000.

B.4.2 WATER SOURCE. Municipal system; 750 gal/min supplied at adequate pressure through three separate pipelines having capacities of 350, 250, and 150 gal/min.

B.4.3 REQUIRED DAILY DEMAND AND FIRE FLOW.

- Capacity factor: 1.5
- Design population: 3,000 X 1.5 = 4,500
- Per capita allowance: 150 gal/day
- Special demands: Negligible

- Required daily demand: 4,500 X 150= 675,000 gal/day, equivalent to a rate of 469 gal/min

- Firefighting flow: 1,500 gal/min for a duration of 2 hours=

- 1,500 X 60 X 2 = 180,000 gallons

B.4.4 STORAGE REQUIREMENTS.

ITEM 1: 50 percent of total daily domestic requirements = 675,000/2 = 337,500 gallons

ITEM 2: Fire demand = (1,500 + 469/2) X 60 X 2 = 208,140 gallons. This item will be reduced by the amount of water available during the period of fire demand under emergency conditions. With the largest pipeline out of service, an emergency supply of 400 gal/min is available. This item becomes 208,140 - (400 X 60 X 2) = 160,140 gallons

ITEM 3: 50 percent of required daily demand plus the fire demand minus the amount of water available in 24 hours under emergency conditions = 337,500 + 208,140 - (400 X 24 X 60) = -30,360 gallons

The first item governs, and storage of about 350,000 gallons should be provided. Storage should be provided as elevated storage because water is delivered from the city under adequate pressure and additional pumping would not be necessary.

B.4.5 WATER MAINS.

- Fire demand rate: (1,500 + 469/2) = 1,735 gal/min
- Maximum day demand: 469 X 2.5 = 1,173 gal/min

Mains must be of adequate size to convey the fire demand rate.