

UNIFIED FACILITIES CRITERIA (UFC)

WATER SUPPLY: WATER STORAGE



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WATER SUPPLY: WATER STORAGE

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U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by \1\ ... /1/)

Change No.	Date	Location

This UFC supersedes TM 5-813-4, dated 20 September 1985. The format of this UFC does not conform to UFC 1-300-01; however, the format will be adjusted to conform at the next revision. The body of this UFC is the previous TM 5-813-4, dated 20 September 1985.

FOREWORD

\1\

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with [USD\(AT&L\) Memorandum](#) dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.


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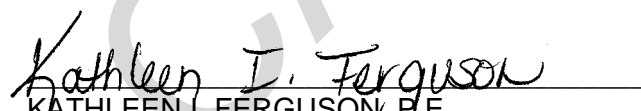
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WATER SUPPLY, WATER STORAGE

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TECHNICAL MANUAL
 No. 5-813-4
 AIR FORCE MANUAL
 No. 88-10, VOLUME 4

HEADQUARTERS
 DEPARTMENTS OF THE ARMY
 AND
 THE AIR FORCE
 WASHINGTON, DC, 20 September 1985

WATER SUPPLY, WATER STORAGE

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*This manual supersedes TM 5-813-4/AFM 88-10, Chap. 4, 2 July 1958.

CHAPTER 1

GENERAL

1-1. Purpose

This manual provides design criteria for water storage requirements at military facilities, gives a typical design analysis for tanks and reservoirs, and provides guidance on the procedures to be followed in selecting sites for such storage works. The manual covers requirements for treated water storage in the distribution system, but not the storage requirements for raw water supplies or fire deluge systems. This manual is applicable to all elements of the Army and Air Force planning and designing water storage facilities at fixed installations.

1-2. Objectives of Storage

a. 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.

b. 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.

c. 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.

d. Distribution system pressures.

(1) System pressure requirements.

(a) Minimum pressures. Water distribution system, including pumping facilities and storage tanks or reservoirs, should be designed so that water pressures of at least 40 lb/in² at ground level will be maintained at all points in the system, including the highest ground elevations in the service area. Minimum pressures of 30 lb/in², 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 20 lb/in² at the hydrants, in new systems. This requirement does not constitute justification for changing existing storage facilities solely for the purpose of increasing residual pressures to 20 psi. Refer to TM 5-813-6/AFM 88-10, Vol. 6 for additional guidance on minimum residual pressures for fire flow.

(b) Maximum pressure. Maximum water pressures in distribution mains and service lines should not normally exceed 75 lb/in² at ground elevation. Static pressures up to 100 lb/in² 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 75 lb/in².

(c) Multiple pressure levels. If an extensive area has pressures higher than 75 lb/in² or lower than 40 lb/in² 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 40 to 75 lb/in² at ground elevation.

(2) Pressure distribution with elevated storage.

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

(b) 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 40 lb/in². Figure 1-1(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.

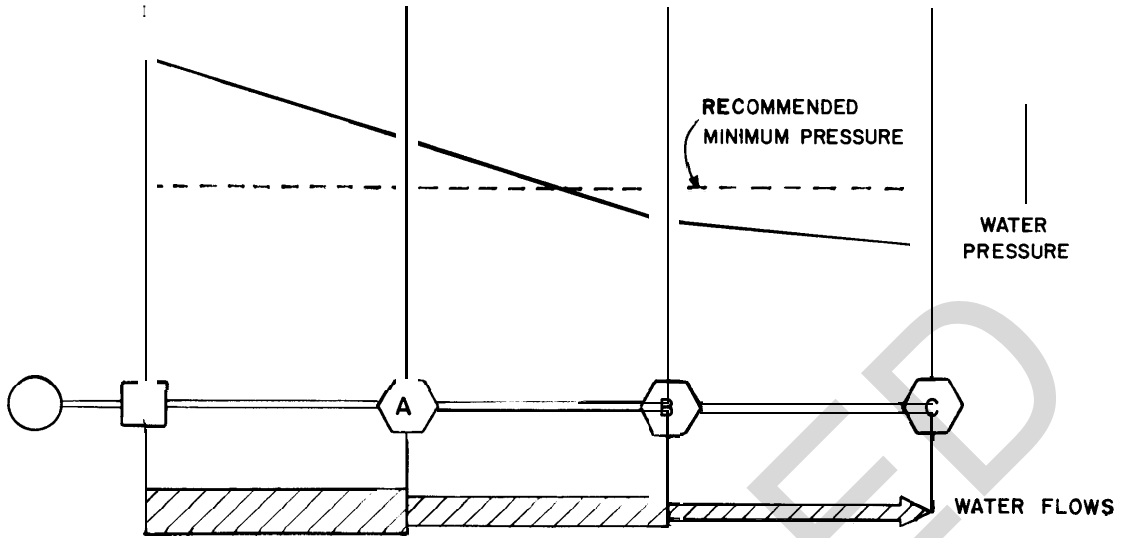
(c) Most elevated storage tanks "float" on the distribution system. That is, the elevated tank

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.

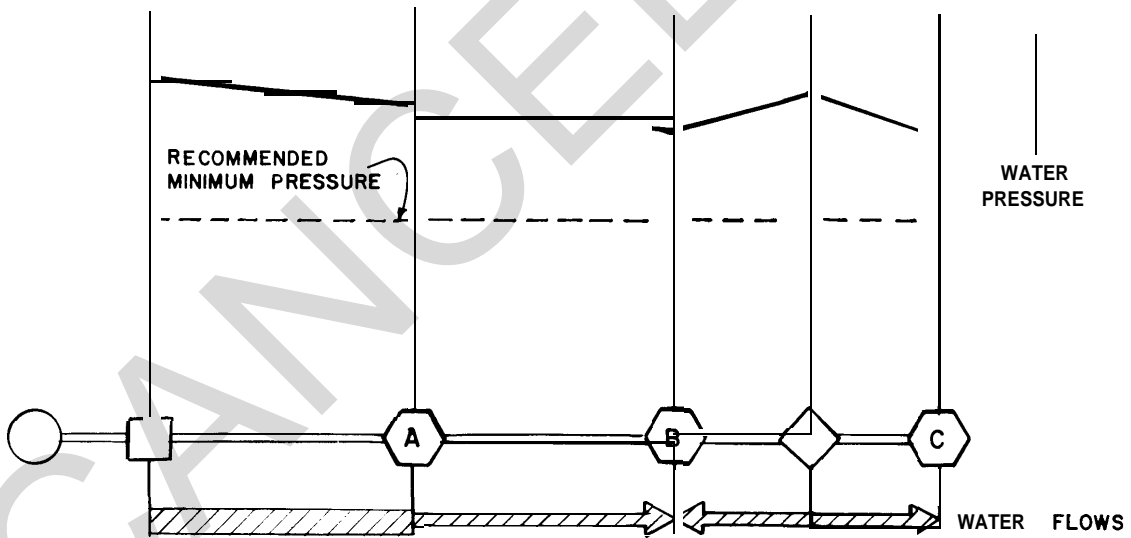
e. *Provision of emergency water supplies.*

(1) *Firefighting flows.* This demand can occur at any time, but may well coincide with other large water demands on the system. Necessary flows for firefighting purposes are as given in TM 5-813-6/AFM 88-10, Vol. 6, and TM 5-813-7/AFM 88-10, Vol. 7. Storage and distribution facilities will include capacity for required firefighting flows at adequate pressures at any point of the installation.

(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

U. S. Army Corps of Engineers

CHAPTER 2

TYPES OF STORAGE

2-1. General

Required storage capacity at military installations is 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

a. 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 repumping to a higher pressure level. Such storage for repumping is common in distribution systems covering a large area, because the outlying service areas are beyond the range of the primary pumping facilities.

b. 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. Concrete reservoirs are generally built no deeper than 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 systems, 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.

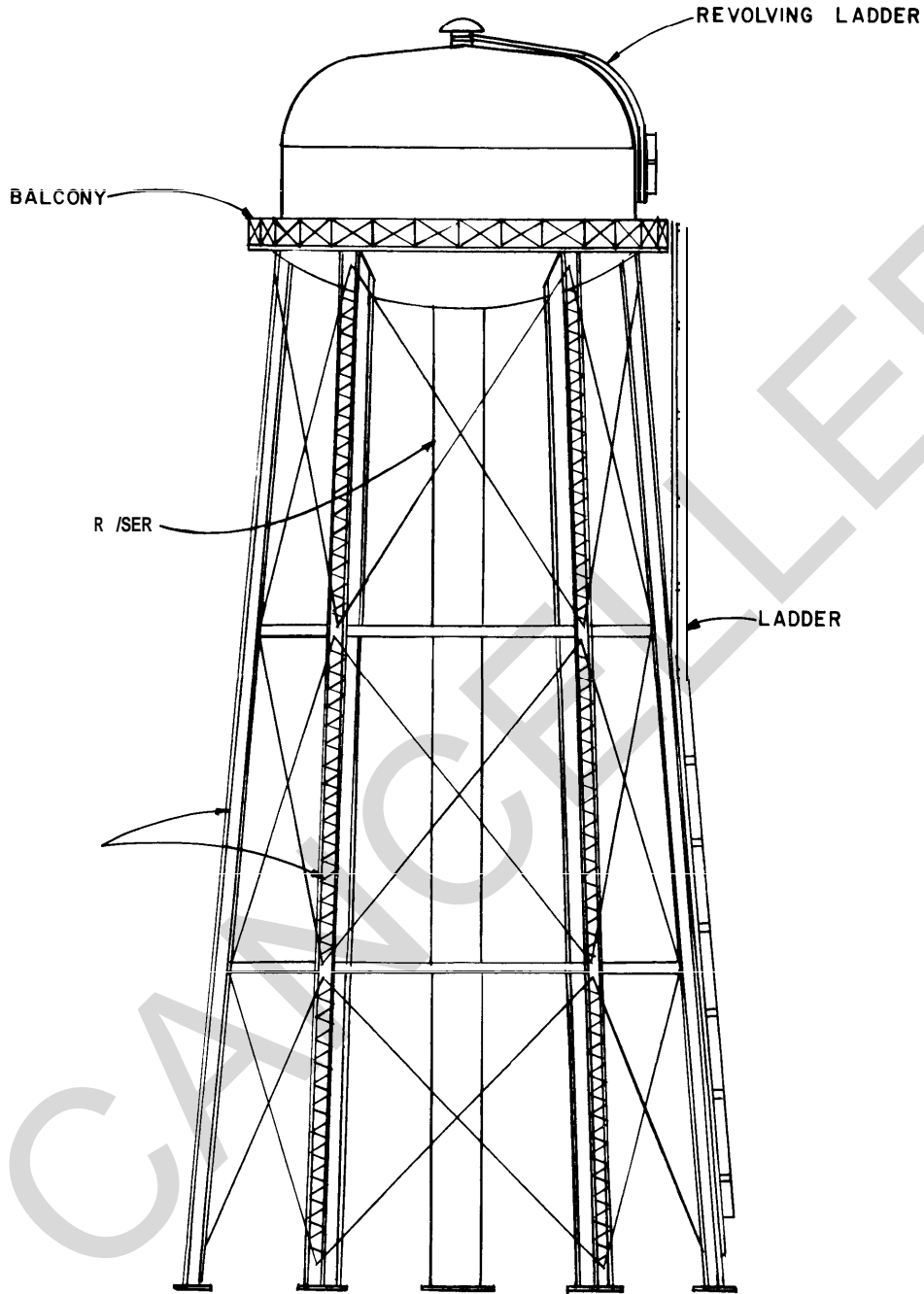
2-3. Elevated Storage

a. 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.

b. 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 esthetic considerations are an important part of the design process. (See American Water Works Association D100, Standard for Welded Steel Tanks for Water Storage (app A).)

c. Standpipe. A standpipe is a tall cylindrical tank normally constructed of steel or reinforced concrete. Only the portion of the storage volume of a standpipe that meets the requirements of *d* below is considered useful storage for pressure equalization purposes. The lower portion of the storage acts to support the useful storage and to provide a source of emergency water supply.

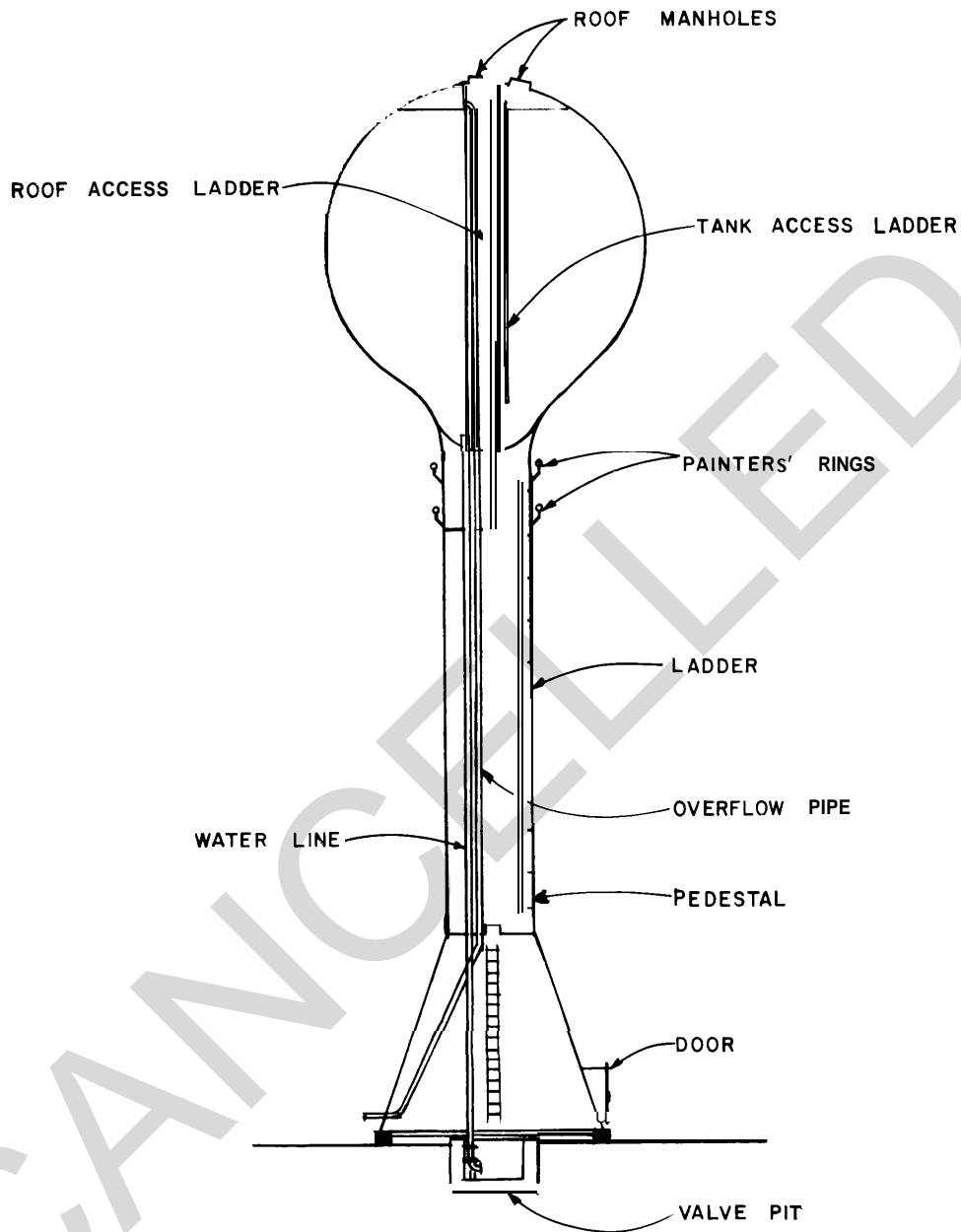
d. Elevated storage. Elevated storage tanks should be located in the areas having the lowest system pressures during intervals of high water use to be effective in maintaining adequate system pressures and flows during periods of peak water demand. These are those of greatest water demand or those farthest 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 75 lb/in² in the system, so as to minimize the required construction cost and heights.



ELEVATED STORAGE TANK

U. S. Army Corps of Engineers

Figure 2-1. Elevated storage tank.



ELEVATED STORAGE TANK
(ALTERNATIVE DESIGN)

U. S. Army Corps of Engineers

Figure 2-2. Elevated storage tank (alternative design).

CHAPTER 3

DETERMINATION OF CAPACITY REQUIREMENTS

3-1. Total Storage Requirements

The amount of water storage provided will conform to the requirements set forth herein. Request for waivers to depart from these requirements will be forwarded to HQDA (DAEN-ECE-G) WASH DC 20314 for Army projects and to HQ USAF/LEEEU WASH DC 20332 for Air Force projects.

a. All military 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 (para. 3-2).

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.

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 (calculated IAW TM 5-813-6/AFM 88-10, Vol. 6); plus 50 percent of the average domestic demand rate plus any industrial or other demand that cannot be reduced during a fire period. This amount will be reduced by the amount of water available under emergency conditions during the period of the fire (TM 5-813-1/AFM 88-10, Vol. 1).

NOTE

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. 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.

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.

b. 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.

c. Amount of water available under emergency conditions.

(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 ca-

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.

(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 reconsidered as the quantity available from the wells having standby power.

(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.

(4) Where the supply is delivered through a single supply main, the maximum amount of storage as determined in paragraph 3-1a will be provided.

(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.

(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.

d. Irrigation requirements. Where irrigation requirements, are justified in arid or semi-arid regions, such irrigation quantities will be included as an industrial requirement of Items 1, 2, and 3 of subparagraph 3-1a and not as a domestic requirement. Water requirements may be increased above those indicated in TM 5-630 for Army installations provided that the increased rates can be substantiated by a local or regional Soil Conservation Service or recognized local authority as the minimum

rate to sustain lawn-type turf. Irrigation requirements for Air Force installations should be 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 military installations, except plant and special projects, should not be less than the amount determined in paragraph 3-1a Item 2, 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

a. 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.

b. 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, in accordance with paragraphs 3-1 and 3-2, will be determined by feasibility studies which take into account all engineering, economic, energy, and environmental factors. Analysis will be in accordance with AFR 178-1 for Air Force projects and AR 11-28 for Army projects.

CHAPTER 4

DESIGN AND CONSTRUCTION OF WATER STORAGE FACILITIES

4-1. Reservoir Covers

All treated water 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 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 reservoir 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 entering the reservoir. Reservoir 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 reservoir so that water in the reservoir does not become stagnant. Minimal flows through the reservoir also help to prevent ice buildup during cold periods.

4-2. 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.

4-3. 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 ac-

tuated instruments. The direct pressure measurements of elevated tanks will be suppressed to read-out 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 telemetering 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 shut-down 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 shut-down.

4-4. Disinfection

Potable water storage facilities, associated piping, and ancillary equipment must be disinfected before use. Disinfection will be accomplished following procedures and requirements of American Water Works Standard D105. In no event will any of the above equipment or facilities be placed in service prior to verification by the supporting medical authority, by bacteriological tests, that disinfection has been accomplished.

4-5. 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.

APPENDIX A

REFERENCES

A-1. Government Publications

a. Department of the Army.

- AR 11-28..... Economic Analysis and Program Evaluation for Resource Management.
- TM 5-630 Repairs and Utilities, Ground Maintenance and Land Management.

b. Department of the Air Force.

- AFR 178-1 Economic Analysis and Program Evaluation for Resource Management.

c. Departments of the Army and Air Force.

- TM 5-813-1/AFM 88-10, Vol. 1 Water Supply: Sources and General Considerations.
- TM 5-813-5/AFM 88-10, Vol. 5 Water Supply: Water Distribution Systems.
- TM 5-813-6/AFM 88-10, Vol. 6 Water Supply: Water Supply for Fire Protection.
- TM 5-813-7/AFM 88-10, Vol. 7 Water Supply: Water Supply for Special Projects.

A-2. Nongovernment Publications

Joint Commission on Accreditation of Hospitals, 875 N. Michigan Avenue, Chicago, Illinois 60661
Accreditation Manual for Hospital, 1979

American Water Works Association Standard, (AWWA) American Water Works Association, 6666 W.
Quincy Avenue, Denver, Colorado 80235

Standards:

- D100 Welded Steel Tanks for Water Storage.
- D105 Disinfection of Water Storage Facilities.

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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 water storage facilities at Army or Air Force installations.

B-2. Example No. 1: Communications base; permanent construction

a. Effective population.

Nonresident: 400

Resident: 700

Total: $700 + (400 \div 3) = 833$

b. Water source. Wells on post; average yield 150 gal/rein each.

c. Treatment. Chlorination.

d. Required daily demand and fire flows.

Capacity factor: 1.5 (TM 5-813-I/AFM 88-10, Vol. 1)

Design population: $833 \times 1.5 = 1,250$

Per capital allowance: 150 gal/d (TM 5-813-1/AFM 88-10, Vol. 1)

Special demands: None

Required daily demand: $1,250 \times 150 = 187,500$ gal/day, equivalent to a rate of 130 gal/min.

Firefighting flow: 500 gal/min for 2 hours (Exact value should be calculated in accordance with TM 5-813-6/AFM 88-10, Vol. 6)

Maximum day demand: $130 \times 2.5 = 325$ gal/min.

e. Well requirements.

Total well yield: Assuming 24-hour/day well operation, one well has sufficient yield to meet the required daily demand rate of 130 gal/rein. However, for firm production capability, it is necessary to have two wells, each capable of 130 gal/rein.

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 150-gal/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.

f. Storage requirement.

Item 1: 50 percent of total daily domestic requirements:

$187,500 \div 2 = 93,750$ gallons.

Item 2: Fire demand:

$$\left(500 + \frac{130}{2} \right) \times 60 \times 2 = 67,800 \text{ gallons.}$$

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 $67,800 - (150 \times 2 \times 60) = 49,800$ gallons.

Item 3: 50 percent of total daily domestic requirements plus the fire demand minus the production of one well in 24 hours: $93,750 + 67,800 - (150 \times 24 \times 60) = -54,450$ gallons.

The largest of the above items, 93,750 gallons, governs the total storage requirements. Storage of not less than 100,000 gallons should be provided. In this case, it is suggested that a 100,000-gallon elevated tank be provided.

g. Water main sizes. The water distribution system will have mains of adequate size to meet peak domestic demand (see TM 5-813-1/AFM 88-10, Vol. 1) and pressure requirements at all locations. General design criteria for water mains is given in TM 5-813-5/AFM 88-10, Vol. 5.

B-3. Example No. 2: Permanent camp.

a. Effective population.

Nonresident: Negligible

Resident: 20,000

b. Water source. Surface supply from river.

c. Treatment. Coagulation, flocculation, sedimentation, filtration, and chlorination.

d. Required daily demand and fire flows.

Capacity factor: 1.15.

Design population: $20,000 \times 1.15 = 23,000$.

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: $(23,000 \times 150) + 400,000 = 3,850,000$ gal/day, equivalent to a rate of 2,674 gal/min.

Maximum day demand: $2,674 \times 2.5 = 6,684$ gal/min.

Firefighting flows:

Quarters: Fire Flow: 1500 gpm Duration: 2 hours = $1500 \times 60 \times 2 = 180,000$ gallons.

(Exact value should be calculated in accordance with TM 5-813-6/AFM 88-10, Vol. 6).

Warehouse (40,000 ft², Type I construction, extra hazard occupancy): 2,800

gal/min for a duration of 3 hours = $2,800 \times 60 \times 3 = 504,000$ gallons.

Hospital (1,500 gal/min for a duration of 2 hours = $1,500 \times 60 \times 2 = 180,000$ gallons.

(Exact value of Fire flow required should be calculated in accordance with TM 5-813-6/AFM 88-10, Vol. 6).

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.

e. Storage requirements.

Item 1: 50 percent of total daily domestic requirements =

$$\frac{(23,000 \times 150) + 400,000}{2} = 1,925,000 \text{ gallons.}$$

Item 2: Fire demand =

$$(2,800 \times 60 \times 3) + \frac{(23,000 \times 150 \times 4)}{24 \times 2} = 719,630 \text{ gallons.}$$

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. TM 5-813-1/AFM 88-10, Vol. 1 recommends that a sufficient number of both raw and finished water pumps be equipped with dual power sources (electric motor—internal combustion engine) or stand-by internal combustion engines to be capable of supplying at least 50 percent of the required daily

demand under emergency conditions. In this case a 1,350 gal/min dual drive pump is included in both the raw water and filtered water pumping equipment. The storage requirement for fire demands becomes $719,630 - (1,350 \times 60 \times 3) = 476,630$ gallons.

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

f. 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.

g. High-lift pumping station. Pumping facilities, similar to those for raw water pumping station, will be provided.

h. Water main sizes. Water mains will be in accordance with the criteria of TM 5-813-5/AFM 88-10, Vol. 5.

B-4. Example No. 3: A barracks, Type 1, Fire resistive construction unsprinkled facilities, floor area 125,000 sq. ft.

a. Effective population. 3,000.

b. Water source. Municipal system; 750 gal/min supplied at adequate pressure through three separate pipelines having capacities of 350, 250, and 150 gal/min.

c. Required daily demand and fire flow.

Capacity factor: 1.5

Design population: $3,000 \times 1.5 = 4,500$

Per capita allowance: 150 gal/day

Special demands: Negligible

Required daily demand: $4,500 \times 150 = 675,000$ gal/day, equivalent to a rate of 469 gal/min.

Firefighting flow: 1,500 gal/min for a duration of 2 hours = $1,500 \times 60 \times 2 = 180,000$ gallons.

(Exact value of fire flow should be in accordance with TM 5-813-6/AFM 88-10, Vol. 6.)

d. Storage requirements.

Item 1: 50 percent of total daily domestic requirements =

$$\frac{675,000}{2} = 337,500 \text{ gallons.}$$

Item 2: Fire demand =

$$\left(1,500 + \frac{469}{2} \right) \times 60 \times 2 = 208,140 \text{ gallons.}$$

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 $208,140 - (400 \times 60 \times 2) = 160,140$ 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 = $337,500 + 208,140 - (400 \times 24 \times 60) = -30,360$ 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.

e. *Water mains.*

$$\text{Fire demand rate: } \left(1,500 + \frac{469}{2} \right) = 1,735 \text{ gal/min.}$$

$$\text{Maximum day demand: } 469 \times 2.5 = 1,173 \text{ gal/min.}$$

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

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