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UNIFIED FACILITIES CRITERIA (UFC)

WATER SUPPLY: WATER DISTRIBUTION

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WATER SUUPLY: WATER DISTRIBUTION

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 5-813-5, dated 3 November 1986. 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 5-813-5, dated 3 November 1986.

FOREWORD

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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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TECHNICAL MANUAL

WATER SUPPLY, WATER DISTRIBUTION

HEADQUARTERS, DEPARTMENT OF THE ARMY
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REPRODUCTION AUTHORIZATION/RESTRICTIONS

TECHNICAL MANUAL
NO. 5-813-5
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NO. 88-10, Volume 5

HEADQUARTERS
DEPARTMENT OF THE ARMY
AND THE AIR FORCE
WASHINGTON, D.C. *3 November 1986*

WATER SUPPLY, WATER DISTRIBUTION

*Supersedes TM 5-813-5/AFM 88-10, Vol 5, 31 January 1963.

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CHAPTER 1

GENERAL

1-1. Purpose and scope. This manual provides criteria for design and construction of potable water distribution systems for fixed military installations. Within the context of this manual, a water distribution system is considered to consist of all mains, service lines, valves, pumps, hydrants, and ancillary equipment needed to carry water from the source of potable water to the various points of use. Water distribution within an individual building or group of buildings is covered in TM 5-810-5/AFM 88-8, Volume 4. This manual is applicable to all elements of the Army or Air Force charged with planning or performing military construction.

1-2. Definitions. The following definitions, in addition to those given in paragraph 1-4, TM 5-813-1/AFM 88-10, Volume 1 are applicable to this manual.

a. Backflow. The flow of any foreign liquids, gases, or other substances into the distributing pipelines of a potable supply of water from any source or sources not intended.

b. Back-siphonage. The backing up, or siphoning, of a foreign liquid into a potable water system; this occurs when the potable water system, at any point or place, is at a pressure less than atmospheric, with an opening or break in the system, thereby drawing the foreign liquid toward the potable water.

c. Cross connection. Any physical connection which provides an opportunity for nonpotable water to contaminate potable water.

d. Distribution mains. All pipelines of the distribution system, except the small service pipes connecting building systems to the supply.

e. Transmission mains. Those pipelines or conduits which carry water from one point to another without intermediate service connections; e.g., pipelines from a pumping station to a reservoir.

1-3. System planning. The distribution system must reliably and economically supply water, in adequate quantities and at adequate pressures, to all water users. In order to plan or design a water distribution system, the location or point of demand must be known or assumed, and the magnitude of each demand known or estimated; water demands may then be categorized by purpose as domestic, industrial, special, or fire protection. Criteria for determining water demands are discussed in TM 5-813-1/AFM 88-10, Volume 1; AFM 88-10, Chapter 6; and TM 5-813-7/AFM 88-10, Volume 7. Criteria for sizing and locating water treatment plants and water storage facilities are presented in TM 5-813-3/AFM 88-10, Volume 3; and TM 5-813-4/AFM 88-10, Volume 4. Sizing of the water treatment plant, water storage facilities, distribution pumps, or distribution mains, is dependent on the size of the other parts of the system. It is not practical to size individual distribution mains without considering the other elements of the system. The effectiveness of any proposed combination of storage, pumping, and distribution works in meeting projected peak demands is best determined by hydraulic analyses of the system. Such hydraulic analyses, usually performed on digital computers, are very helpful to system planning.

1-4. Cross connections. (Cross connections and backflow prevention for Air Force facilities are defined in AFM 85-21).

a. Avoidance of cross connections. If fires are to be fought with both potable and nonpotable supplies, separate distribution systems must be used to deliver the two types of water to the required area. Hydrants or other connections for each system should be suitably identified to discourage improper use. Standby water reservoirs serving fire protection systems are sometimes filled from both potable and nonpotable supplies. If this is the case, the potable water shall be discharged to the reservoir through an air break not less than 12 inches above the maximum water level of the reservoir. In a similar manner, where potable water is to be used as gland seal on a pump handling nonpotable water, the potable water must be stored in a tank with an air gap between the end of the water supply line and the top of the tank. Special care must also be taken of such items as valve pits and water storage facilities to ensure that surface water runoff cannot enter potable water systems. Other situations that can result in back-siphonage are flexible hose having one end immersed in nonpotable water and the other end connected to a potable water hose bib, potable waterlines entering swimming pools without air gaps, lawn irrigation systems with sprinkler heads flush with the ground, and improper connections at vehicle wash racks.

b. Prevention of backflow. Devices for the prevention of backflow include air gaps and reduced-pressure-principle backflow preventers. Air gap distances should be at least twice the diameter of the water supply line, and reduced-pressure-principle backflow prevention devices should meet the criteria of American Water Works Association (AWWA) C506 (See app A for references). Double check valves for backflow prevention are not considered suitable and should not be used. Back-siphonage can be prevented with air gaps, atmospheric-type vacuum breakers, or pressure-type vacuum breakers.

CHAPTER 2

PRESSURE REGULATION ALTERNATIVES

2-1. General. The pressure levels for the distribution system are set by chapter 4. Alternative means to maintain these pressures consist of gravity systems, direct pressure systems, pneumatic system or a combination of the above. Pressure regulating valves are available to reduce system pressures if required.

2-2. Gravity pressure systems. This is the preferred method of maintaining adequate pressure in the system. Gravity pressure systems are inherently associated with elevated storage. A storage facility provides a reservoir in which the inflow and outflow of water can better match the hourly consumer demand and can be a supply source during emergency situations such as interruptions in the normal supply service or heavy demands for fire fighting. Reservoirs should be located within or adjacent to load centers (i.e., areas of high demand) of the distribution grid to meet water demands in those areas without causing high velocities and head losses in the distribution mains. The pressure in the system supplying water to the storage facility needs to be sufficient to fill the reservoir. If it is not, booster pumps may be required. Two types of tanks may be used in a gravity pressure system: elevated and ground storage tanks.

a. Elevated tank. Where ground elevations are relatively uniform, an elevated tank will be considered to maintain pressure in lieu of ground storage facilities where practical. The tank will be adequately sized in accordance with TM 5-813-4/AFM 88-10, Vol. 4. The height of the tank will be determined from the topography of the area served, the height of the buildings and the pressure losses in the distribution system. Standard and special designs are available in sizes up to 3,000,000 gallons. Standard design will be utilized except where special conditions warrant other designs. Special designs on Air Force projects will be subject to approval by HQ USAF/LEEEU, Washington, D.C. 20332. In addition, altitude valves, check valves and shut off valves are necessary to control the level of water in the tank and to provision or isolate portions of the distribution system during emergencies. These are to be contained in a valve pit near the base of the tank, protected from freezing, and will provide for appropriate connections to the distribution system.

b. Ground level storage. Ground level storage can consist of steel standpipes and steel or concrete ground storage reservoirs. These are to be designed where there is sufficient difference in ground elevation to maintain adequate pressure in the distribution system. Concrete reservoirs can be designed for any size system, but are more often used for larger sizes, i.e., those exceeding 1,000,000 gallons. Standpipes of 6 to 20 feet in diameter may be installed for small systems. If the differences in natural ground elevations is insufficient to maintain pressures, booster pumps may be required in conjunction with ground storage to increase system pressure.

c. Sizing of storage volume. The maximum and minimum elevations of water in the tank determine the pressure in the distribution system and should be designed accordingly. The required volume determines the surface area of the tank which is based on daily use and fire flow demand. Refer to TM 5-813-4/AFM 88-10, Vol. 4.

2-3. Direct-pressure systems. A direct pressure distribution system is one in which no elevated storage is provided, and the required distribution pressures are maintained only by pumping facilities. A ground level storage tank may be provided to serve as an intake supply for the pumping facilities. Direct-pressure distribution systems will be considered only where the military use or special requirements will not permit the utilization of elevated storage tanks. Caution must be used in design to reduce surge pressure and compensate for variable volume demands. Provisions must be made to ensure the availability of sufficient supply to meet fire and emergency demands. The pumping facilities in a direct-pressure system must have firm capacities equal to or greater than the peak demand rates exerted on the system. The firm capacity of a pumping facility is the total pumping capacity with the largest pump out of service. Automatic controls are available which react to pressure sensors and cycle the pumps according to a sequence which may be predetermined by the operator.

a. Pumping stations. For variable flow requirements, consideration will be given to variable speed pumps, multiple pumps with stage control, flow regulating valves, or flow recirculation. The usual location is at the supply and treatment facility. Additional units may be located within the distribution system. Consideration should be given to providing a by-pass around pumps in the distribution system so that some flow may be maintained even when the pump is out of service. The pumps and associated equipment shall be contained in a vault or pump house to protect the equipment from the environment.

b. Line boosters. Line booster stations may be designed where system head loss dictates their use. This may include distribution system areas that are remote from pumping stations, high rise building areas where normal pressure is inadequate, localized areas of higher elevation or extensions to existing distribution system where the cost of additional elevated storage is prohibitive. These pumps may be submersible turbine pumps, mounted in housings which can be installed in a water main much the same as a regular section of pipe. The pumps may be buried underground. As with all electrical-mechanical devices, they are subject to maintenance needs. Therefore, provision must be made for future maintenance which may include excavation of the installation. Other types of pumps, most commonly centrifugal, may be installed in a vault or pump house. This installation is designed as any other pump station.

c. Multiple pressure levels. In multiple pressure level distribution systems, where pumps are installed in the system, the designer should check for circulation around the pumps. If recirculation of water from the high pressure system to the low pressure system is possible, which would cause the water to be pumped twice, distribution line valves must be closed or check valves should be installed.

2-4. Pneumatic System. A hydropneumatic tank "riding" on the system serves two functions. First, it can act as a reservoir of water for emergency supply for a short period of time such as a supply for a sprinkler head; second, it can act as an air spring or piston and is a reservoir of stored energy to maintain pressure in the system and help avoid short-cycling of the pumps.

a. Applicability. Hydropneumatic distribution systems are applicable where demands are less than 500 gallons per minute. Hydropneumatic tanks will be designed and constructed in accordance with ASME Boiler and Pressure Vessel Code, Section VIII.

b. Pressure settings. The low pressure setting on the hydropneumatic tank is determined by distribution system requirements. The recommended minimum operating pressure is 30 pounds per square inch (psi), at the highest ground elevation in the distribution system. The high pressure setting on the hydropneumatic tank is dependent on the maximum allowable pressure in the distribution system. The recommended maximum operating pressure is 100 psi. For a specific application, the pressure variation in the tank is normally about 20 psi. The low water level (water level at the low pressure setting) must be high enough to provide a water seal. At the low water level, the water remaining in the tank should be at least 10 percent of the capacity of the tank. The high water level should be calculated to provide maximum efficiency. The pumps will be sized to deliver 125 percent of the calculated peak demand of the distribution system. The tank size will be at least 10 times the rated capacity of the pump. The tank will be sized so that the pump cycles not less than 4 times per hour, nor more than 10 times per hour, unless the pump motor horse-power rating exceeds 50, in which case the maximum number of cycles will be 6 per hour. Completely automatic hydropneumatic tank controls are available to maintain proper operating conditions (correct air-water volume ratios) during each pump cycle. An auxiliary air compressor-type, air charging system will be used for tanks larger than 750 gallons and pressures higher than 75 psi. An air volume control valve operation will be used to maintain correct air-water volume ratios for all other applications.

2-5. Pressure regulating valves. Pressure regulating valves function to reduce an existing high pressure to a uniform downstream pressure. Although this function can be accomplished by partially closed line valves, this method requires manual operation or motorized operators with remote control and continuous monitoring. Automatic pressure reducing and sustaining valves are available which react to distribution system pressures. These valves operate on two principles.

a. Direct action. A direct-acting regulator cannot regulate pressure closely if considerable range of variation between the wide open and nearly closed positions is required. The regulated pressure is influenced considerably by variations in the high-pressure side, and a great differential must always exist between the high side and the regulated side. Such regulators give excellent service in small sizes where accurate regulation is not important or where the rate of flow is fairly steady.

b. Pilot operated. In water distribution regulation, it is important to sustain the pressure as load increases. With pilot-operated reducing valves, it is possible to get extremely close regulations at any flow up to the full capacity of the valve wide open. Pilot-operated valves may chatter and perform improperly when flow is very small and the disc or piston is close to the seat. Each valve must be provided with two gate valves, permitting it to be shut off for repairs without interfering with other valves. Pressure regulators, like other automatic equipment, should be inspected weekly to insure good operation and discover the need for preventive maintenance before a serious breakdown occurs.

CHAPTER 3

DISTRIBUTION MAINS

3-1. Main sizes. Maximum and minimum distribution systems pressure requirements are given in chapter 4. Distribution system hydraulic analysis are given in appendix B. Water distribution mains of various materials are readily available in sizes ranging from 6 to 48 inches inside diameter; large pipes up to 144 inches and greater can be specially made. Minimum diameter for distribution mains and fire branches is 6 inches.

a. Domestic requirements. The system should be capable of delivering the peak domestic demand as described in TM 5-813-1/AFM 88-10, Volume 1, plus any special requirements, at pressures not lower than 30 pounds per square inch at ground elevation. The required daily demands should be determined by calculating the effective populations of various areas to be served and applying the appropriate per capita water allowances (TM 5-813-1/AFM 88-10, Volume 1). Guidance on the estimation of demands at special projects is given in TM 5-813-7/AFM 88-10, Volume 7. For small installations not having elevated storage, the peak domestic demand will be determined on a fixture basis (TM 5-810-5/AFM 88-8, Volume 4).

b. Fire Flows. The distribution system will be designed to deliver the necessary fire flow requirements, the required daily demand (TM 5-813-1/AFM 88-10, Volume 1), and any industrial or special demands which cannot be reduced during a fire. When only hose streams are supplying the required fire flow streams, residual ground level water pressures at fire hydrants should be not less than 10 pounds per square inch. If sprinkler systems are used, residual pressures adequate for proper operation of the sprinkler systems must be maintained. Specific guidance as to fire flows and pressure required for various structures and types of fire protection systems is given in AFM 88-10, Chapter 6 for Air Force applications and MIL-HDBK-1008 for Army applications.

c. Friction losses. In computing head losses due to friction in a distribution system, the Hazen-Williams formula, as given below, will be used.

$$V = 1.318\, CR^{0.63}S^{0.54} \qquad \text{(eq 3-1)}$$

where

V = the mean velocity of the flow, in feet per second.

R = the hydraulic radius of the pipe in feet, i.e., the cross-sectional area of a flow divided by the wetted perimeter of the pipe. For a circular pipe flowing full, the hydraulic radius is equal to one-fourth the pipe diameter.

S = the friction head loss per unit length of pipe (feet per feet).

C = a roughness coefficient, values of which depend on the type and condition of pipe. Typical values of this coefficient are shown in table 3-1.

Table 3-1. Pipe materials and valves

Pipe Material	C
Concrete (regardless of age)	130
Cast iron:	
New	130
5 years old	120
20 years old	100
Welded steel, new	120
Wood stave (regardless of age)	120
Asbestos-cement	130
Plastic (PVC, Fiberglass)	130

Values as high as 150 are claimed for plastic pipe. The values shown in table 3-1 are considered practical limits because of losses that may result due to fittings and valves, and because of improper installation. Hydraulic analyses will normally be made using a value of 100 for the roughness coefficient. However, consideration should be given to the use of coefficients greater than 100 when specifying concrete, asbestos-cement, or plastic pipe under conditions that experience has shown will not seriously reduce the carrying capacity of these pipes, within the anticipated economic life of the project. Coefficients greater than 130 should not be used. In some cases, expansions to existing distribution networks, rather than entirely new networks, must be planned. In such instances, it may be desirable to determine the roughness coefficients of the existing pipelines through a series of coefficients tests. These involve isolating sections of pipeline to the greatest extent possible, measuring the flow through the pipelines, and monitoring the changes in the hydraulic gradient between different points on the same pipes. This information can be used to derive the friction head loss per unit length of pipe, and, in turn, a roughness coefficient can be calculated.

d. Fire-hydrant branches. Fire-hydrant branches (from main to hydrant) should not be less than 6 inches in diameter and as short in length as possible, preferably not longer than 50 feet with a maximum of 300 feet.

3-2. Location of mains.

a. General. Mains should be located along streets in order to provide short hydrant branches and service connections. Mains should not be located under paved or heavily traveled areas and should be separated from other utilities to ensure the safety of potable water supplies, and that maintenance of a utility will cause a minimum of interference with other utilities.

b. Distribution system configuration. The configuration of the distribution system is determined primarily by size and location of water demands, street patterns, location of treatment and storage facilities, and topography. Two patterns of distribution main systems commonly used are the branching or dean end, and gridiron patterns.

(1) *Branching system.* The branching system shown in figure 3-1 evolves if distribution mains are extended along streets as the service area expands. Dead ends in the distribution system are undesirable and should be avoided to the extent possible.

(2) *Gridiron system.* The second distribution configuration is the gridiron pattern shown in figure 3-1. The gridiron system has the hydraulic advantage of delivering water to any location from more than one direction, thereby avoiding dead ends. The use of a gridiron pattern looped feeder system is preferable to the use of a gridiron pattern with a central feeder system because the looped feeder supplies water to the area of greatest demand from at least two directions. A looped feeder system should be used for water distribution systems whenever practicable. Although it is advantageous to have all water users located within a grid system, it is often impracticable to do so. Water is normally delivered to a remote water user, or a small group of users, by a single distribution main. Therefore, the majority of the water users are served within a gridiron system while the outlying water users are served by mains branching away from the gridiron system. Branching mains should be avoided to the greatest extent possible.

c. Horizontal separation between water mains and sewers. Water mains should be laid horizontally, a minimum of 10 feet, from any point of existing or proposed sewer or drain line. Water mains and sewers must not be installed in the same trench. If any conditions prevent a horizontal separation of 10 feet, a minimum horizontal spacing of 6 feet can be allowed, but the bottom of the water main must be at least 12 inches above the top of the sewer. Where water mains and sewers follow the same roadway, they will be installed on opposite sides of the roadway, if practicable.

d. Water main sewer crossings. Where water mains and sewers must cross, the sewer will have no joint within 3 feet of the water main unless the sewer is encased in concrete for a distance of at least 10 feet each side of the crossing. If special conditions dictate that a water main be laid under a gravity-flow sewer, the sewer pipe should be fully encased in concrete for a distance of 10 feet each side of the crossing, or should be made of pressure pipe with no joint located within 3 feet horizontally of the water main, as measured perpendicular to the water main. Pressure sewer pipe shall always cross beneath water pipe and a minimum vertical distance of 2 feet between the bottom of water pipe and the top of pressure sewer pipe shall be maintained. The sewer must be adequately supported to prevent settling.

e. Protection in airfield pavement areas. Water mains should not be located under airfield pavement areas if other locations are available and economically feasible. Special protection of the mains are required when alternative locations are not available and it is necessary to locate water mains under pavement areas on which aircraft move under their own power. The amount of protection needed is dependent upon the importance of maintaining a supply of water to the area served by the main, and on the availability of emergency water supplies to the affected area. The degrees of protection should be considered as follows:

(1) *Minimum protection.* The water main must be enclosed in a vented, open-end, outer conduit from which the main can be removed for repairs or replacement. The outer conduit must have sufficient strength to support all foreseeable loadings.

(2) *Intermediate protection.* Intermediate protection requires the water service to be carried under the airfield pavement by dual waterlines enclosed in an outer conduit or, preferably, in separate conduits.

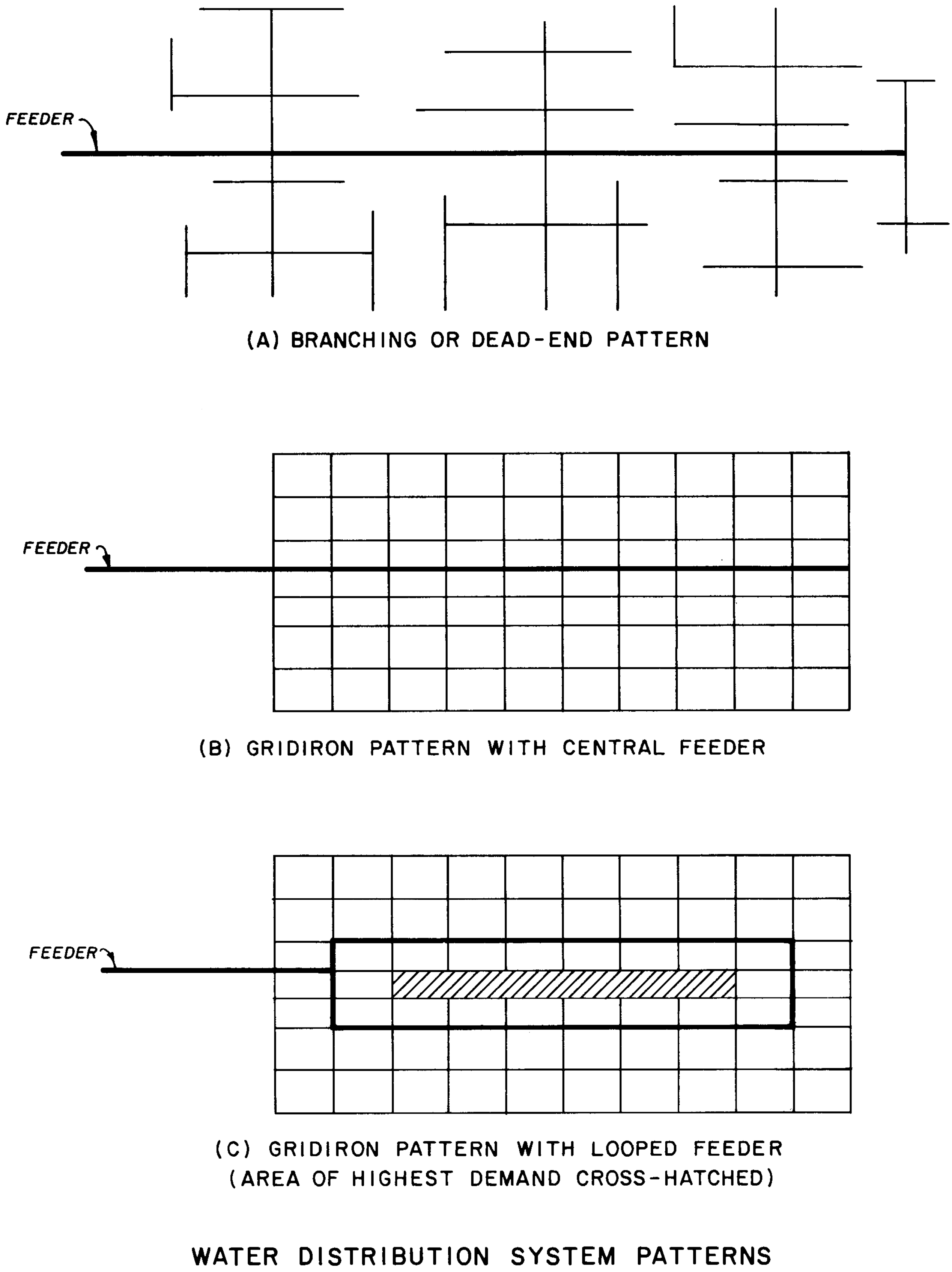

Figure 3-1. Water distribution system patterns.

(3) *Maximum protection.* Where more than one utility crosses the airfield pavement and individual crossings would be more expensive than a combined crossing, the utilities will be enclosed in a utility tunnel of sufficient size for in-place repairs. Special precautions must be taken in the placement and protection of individual utility lines within the tunnel to ensure that failure of one utility does not affect the service of the others. Special protection of mains is not required where the mains are located beneath pavement areas that are not normally subject to the movement of aircraft under their own power, such as hangar access aprons on which aircraft would be towed.

3-3. Dual water supplies.

a. Applicability. Dual water supply systems consist of independent pipe networks supplying two grades of water to users. The higher quality water is used for domestic purposes such as drinking, cooking, dishwashing, laundry, cleaning, and batching; the lower quality water may be used for toilet flushing, fire fighting, lawn and garden watering, and commercial or industrial uses not requiring high quality water. Dual water supply systems are not feasible except under unusual circumstances. A dual water supply might be utilized when the only available water supply is brackish and the cost of a dual system is less than the demineralization cost of all the water supplied to users; or when only a limited quantity of higher quality water is available, and it is more economical to construct a dual system than to implement the required treatment of the lower quality water. If a dual water supply system is established and the lower quality water use might result in human contact or ingestion (e.g., toilet flushing, lawn and garden watering), both water supplies must be disinfected.

b. Evaluation of dual water supply system. The design of dual water supplies will be determined using results of feasibility studies which have substituted all engineering, economic, energy, and environment factors. If a dual water supply system is installed and a brackish water is used as the lower quality water, metallic pipes and plumbing facilities exposed to the brackish water may have considerably short lifespans than similar facilities exposed to water of better mineral quality. There will be no connection between the two pipe networks of a dual distribution system.

3-4. Recycling used water. There are operations that generate effluent water than can be reused for the same operation after minimal treatment. This does not constitute a dual system. Examples of such effluents are laundry wastes, vehicle washrack waste water, and plating operations waste water. Recycling of such water should be practiced wherever feasible.