

WATER WORKS DESIGN MANUAL

PREAMBLE

AscenTrust, LLC. Standard – This Design Manual consists only of proven technologies and is intended to serve as a guide in the design and preparation of plans and specifications for public water supply systems. This manual is to be used only by our design and engineering staff as a point of reference in discussions with the reviewing authority where the reviewing authority may not have a complete set of design documents and standard drawings, to suggest limiting values for items upon which an evaluation of such plans and specifications may be made by the reviewing authority, and to establish, as far as practicable, uniformity of practice. Because statutory requirements and legal authority pertaining to public water supplies are not uniform among states and much less in the International Environment, and since conditions and administrative procedures and policies also differ, the use of this standard must be adjusted to these variations.

The terms shall and must are used where practice is sufficiently standardized to permit specific delineation of requirements or where safeguarding of the public health justifies such definite action. Other terms, such as should, recommended, and preferred, indicate desirable procedures or methods, with deviations subject to individual consideration. Most quantified items in this document are cited in US customary units. Metric equivalent quantities, follow in brackets where compound units are involved. The metric unit symbols follow International System conventions. In the event of a conflict between quantities in US units and the metric equivalent the quantity in US units shall take precedence.

It is not possible to cover recently developed processes and equipment in this Document. However, it is our policy is to encourage, rather than obstruct, the development of new processes and equipment. Recent developments may be acceptable to individual states or Sovereign Nations, if they meet at least one of the following conditions:

1. Have been thoroughly tested in full scale comparable installations under competent supervision,
2. Have been thoroughly tested as a pilot plant operated for a sufficient time to indicate satisfactory performance, or
3. A performance bond or other acceptable arrangement has been made so the owners or official custodians are adequately protected financially or otherwise in case of failure of the process or equipment.

The Senior Engineer, the major author of this document, welcomes comments from industry professionals and due consideration will be given to these suggestions. Appropriate changes to this document will be made in recognition of these comments.

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PART 1 - SUBMISSION OF PLANS

1.0 GENERAL: All reports, final plans specifications, and design criteria should be submitted at least 60 days prior to the date on which action by the reviewing authority is desired. Environmental Assessments, and permits for construction, to take water, for waste discharges, for stream crossings, etc., may be required from other federal, state, or local agencies. Preliminary plans and the engineer's report should be submitted for review prior to the preparation of final plans. No approval for construction can be issued until final, complete, detailed plans and specifications have been submitted to the reviewing authority and found to be satisfactory. Documents submitted for formal approval shall include but not be limited to:

- A. engineer's report, where pertinent,
- B. summary of the design criteria,
- C. operation requirements, where applicable,
- D. general layout,
- E. detailed plans,
- F. specifications,
- G. cost estimates.
- H. water purchase contracts between water supplies, where applicable,
- I. other information as required by reviewing authority.

Where the Design/Build construction concept is to be utilized, special consideration must be given to: designation of a project coordinator; close coordination of design concepts and submission of plans and necessary supporting information to the reviewing authority; allowance for project changes that may be required by the reviewing authority; and reasonable time for project review by the reviewing authority.

1.1 ENGINEER'S REPORT: The engineer's report for water works improvements shall, where pertinent, present the following information:

1.1.1 General information, including

- a. description of the existing water works and sewerage facilities,
- b. identification of the municipality or area served,
- c. name and mailing address of the owner or official custodian.
- d. imprint of professional engineer's seal or conformance with engineering registration requirements of the individual state or province.

1.1.2 Extent of water works system, including

- a. description of the nature and extent of the area to be served,
- b. provisions for extending the water works system to include additional areas,
- c. appraisal of the future requirements for service, including existing and potential industrial, commercial, institutional, and other water supply needs.

1.1.3 Justification of project: Where two or more solutions exist for providing public water supply facilities, each of which is feasible and practicable, discuss the alternatives. Give reasons for selecting the one recommended, including financial considerations, operational requirements, operator qualifications, reliability, and water quality considerations.

1.1.4 Soil, groundwater conditions, foundation problems, including description of:

- a. the character of the soil through which water mains are to be laid,
- b. foundation conditions prevailing at sites of proposed structures,
- c. the approximate elevation of ground water in relation to subsurface structures.

1.1.5 Water use data, including

- a. a description of the population trends as indicated by available records, and the estimated population which will be served by the proposed water supply system or expanded system 20 years in the future in five year intervals or over the useful life of critical structures/equipment,
- b. present water consumption and the projected average and maximum daily demands, including fire flow demand ([see Section 1.1.6](#)),
- c. present and/or estimated yield of the sources of supply,
- d. unusual occurrences.

1.1.6 Flow requirements, including

- a. hydraulic analyses based on flow demands and pressure requirements (See Section 8.1.1)
- b. fire flows, when fire protection is provided, meeting the recommendations of the Insurance Services Office or other similar agency for the service area involved.

1.1.7 Sources of water supply: Describe the proposed source or sources of water supply to be developed, the reasons for their selection, and provide information as follows:

1.1.7.1 Surface water sources, including

- a. hydrological data, stream flow and weather records,
- b. safe yield, including all factors that may affect it,
- c. maximum flood flow, together with approval for safety features of the spillway and dam
- d. from the appropriate reviewing authority,
- e. description of the watershed, noting any existing or potential sources of contamination
- f. (such as highways, railroads, chemical facilities, land/water use activities, etc.) which may affect water quality,
- g. summarized quality of the raw water with special reference to fluctuations in quality, changing meteorological conditions, etc.

- h. source water protection issues or measures, including erosion and siltation control structures, that need to be considered or implemented.

1.1.7.2 Groundwater sources, including

- a. sites considered,
- b. advantages of the site selected,
- c. elevations with respect to surroundings,
- d. probable character of formations through which the source is to be developed,
- e. geologic conditions affecting the site, such as anticipated interference between proposed and existing wells,
- f. summary of source exploration, test well depth, and method of construction; placement of liners or screen; test pumping rates and their duration; water levels and specific yield; water quality,
- g. sources of possible contamination such as sewers and sewage treatment/disposal facilities, highways, railroads, landfills, outcroppings of consolidated water-bearing formations, chemical facilities, waste disposal wells, agricultural uses, etc.
- h. wellhead protection measures being considered (see Section 3.2.3.2 and 3.2.3.3).

1.1.8 Proposed treatment processes: Summarize and establish the adequacy of proposed processes and unit parameters for the treatment of the specific water under consideration. Alternative methods of water treatment and chemical use should be considered as a means of reducing waste handling and disposal problems. Bench scale test, pilot studies, or demonstrations may be required to establish adequacy for some water quality standards.

1.1.9 Sewerage system available: Describe the existing sewerage system and sewage treatment works, with special reference to their relationship to existing or proposed water works structures which may affect the operation of the water supply system, or which may affect the quality of the supply.

1.1.10 Waste disposal: Discuss the various wastes from the water treatment plant, their volume, proposed treatment and points of discharge. If discharging to a sanitary sewerage system, verify that the system, including any lift stations, is capable of handling the flow to the sewage treatment works and that the treatment works is capable and will accept the additional loading.

1.1.11 Automation: Provide supporting data justifying automatic equipment, including the servicing and operator training to be provided. Manual override must be provided for any automatic controls. Highly sophisticated automation may put proper maintenance beyond the capability of the plant operator, leading to equipment breakdowns or expensive servicing. Adequate funding must be assured for maintenance of automatic equipment.

1.1.12 Project sites, including

- a. discussion of the various sites considered and advantages of the recommended ones,
- b. the proximity of residences, industries, and other establishments,
- c. any potential sources of pollution that may influence the quality of the supply or interfere with effective operation of the water works system, such as sewage absorption systems, septic tanks, privies, cesspools, sink holes, sanitary landfills, refuse and garbage dumps, etc.

1.1.13 Financing, including

- a. estimated cost of integral parts of the system,
- b. detailed estimated annual cost of operation,
- c. proposed methods to finance both capital charges and operating expenses.

1.1.14 Future extensions: Summarize planning for future needs and services.

1.2 PLANS: Plans for waterworks improvements shall, where pertinent, provide the following:

1.2.1 General layout, including

- a. suitable title,
- b. name of municipality, or other entity or person responsible for the water supply,
- c. area or institution to be served,
- d. scale,
- e. north point,
- f. datum used,
- g. boundaries of the municipality or area to be served,
- h. date, name, and address of the designing engineer,
- i. imprint of professional engineer's seal or conformance with engineering registration requirements of the individual state,
- j. legible prints suitable for reproduction,
- k. location and size of existing water mains,
- l. location and nature of existing water works structures and appurtenances affecting the proposed improvements, noted on one sheet.

1.2.2 Detailed plans, including

- a. stream crossings, providing profiles with elevations of the stream bed and the normal and extreme high and low water levels,
- b. profiles having a horizontal scale of not more than 100 feet to the inch and a vertical scale of not more than 10 feet to the inch, with both scales clearly indicated,
- c. location and size of the property to be used for the groundwater development with respect to known references such as roads, streams, section lines, or streets,

- d. topography and arrangement of present or planned wells or structures, with contour intervals not greater than two feet,
- e. elevations of the highest known flood level, floor of the structure, upper terminal of protective casings and outside surrounding grade, using United States Coast and Geodetic Survey, United States Geological Survey or equivalent elevations where applicable as reference,
- f. plat and profile drawings of well construction, showing diameter and depth of drill holes, casing and liner diameters and depths, grouting depths, elevations and designation of geological formations, water levels and other details to describe the proposed well completely,
- g. location of all existing and potential sources of pollution which may affect the water source or underground treated water storage facilities,
- h. size, length, and materials of proposed water mains,
- i. location of existing or proposed streets; water sources, ponds, lakes, and drains; storm, sanitary, combined and house sewers; septic tanks, disposal fields and cesspools,
- j. schematic flow diagrams and hydraulic profiles showing the flow through various plant units,
- k. piping in sufficient detail to show flow through the plant, including waste lines,
- l. locations of all chemical storage areas, feeding equipment and points of chemical application (see Part 5),
- m. all appurtenances, specific structures, equipment, water treatment plant waste disposal units and points of discharge having any relationship to the plans for water mains and/or water works structures,
- n. locations of sanitary or other facilities, such as lavatories, showers, toilets, and lockers, when applicable or required by the reviewing authority,
- o. locations, dimensions, and elevations of all proposed plant facilities,
- p. locations of all sampling taps,
- q. adequate description of any features not otherwise covered by the specifications.

1.3 SPECIFICATIONS: Complete, detailed technical specifications shall be supplied for the proposed project, including

- A. a program for keeping existing water works facilities in operation during construction of additional facilities so as to minimize interruption of service,
- B. laboratory facilities and equipment,
- C. the number and design of chemical feeding equipment (see Section 5.1),
- D. procedures for flushing, disinfection and testing, as needed, prior to placing the project in service,
- E. materials or proprietary equipment for sanitary or other facilities including any necessary backflow or back-siphonage protection.

1.4 DESIGN CRITERIA: A summary of complete design criteria shall be submitted for the proposed project, containing but not limited to the following:

- A. long-term dependable yield of the source of supply,
- B. reservoir surface area, volume, and a volume-versus-depth curve, if applicable,
- C. area of watershed, if applicable,
- D. estimated average and maximum day water demands for the design period,
- E. number of proposed services,
- F. fire fighting requirements,
- G. flash mix, flocculation and settling basin capacities,
- H. retention times,
- I. unit loadings,
- J. filter area and the proposed filtration rate,
- K. backwash rate,
- L. feeder capacities and ranges.
- M. minimum and maximum chemical application rates.

1.5 REVISIONS TO APPROVED PLANS: Any substantial deviations from approved plans or specifications must be approved by the reviewing authority before such changes are made. These include, but are not limited to deviations in: capacity, hydraulic conditions, operating units, the functioning of water treatment processes, or the quality of water to be delivered. Revised plans or specifications should be submitted in time to permit the review and approval of such plans or specifications before any construction work, which will be affected by such changes, is begun.

1.6 ADDITIONAL INFORMATION REQUIRED: The reviewing authority may require additional information which is not part of the construction drawings, such as head loss calculations, proprietary technical data, copies of deeds, copies of contracts, etc.

PART 2 - GENERAL DESIGN CONSIDERATIONS

2.0 GENERAL: The design of a water supply system or treatment process encompasses a broad area. Application of this part is dependent upon the type of system or process involved.

2.1 DESIGN BASIS: The system including the water source and treatment facilities shall be designed for maximum day demand at the design year.

2.2 PLANT LAYOUT: Design shall consider

- A. functional aspects of the plant layout,
- B. provisions for future plant expansion,
- C. provisions for expansion of the plant waste treatment and disposal facilities,

- D. access roads,
- E. site grading,
- F. site drainage,
- G. walks,
- H. driveways,
- I. chemical delivery.

2.3 BUILDING LAYOUT: Design shall provide for:

- A. adequate ventilation,
- B. adequate lighting,
- C. adequate heating,
- D. adequate drainage,
- E. dehumidification equipment, if necessary,
- F. accessibility of equipment for operation, servicing, and removal,
- G. flexibility of operation,
- H. operator safety,
- I. convenience of operation,
- J. chemical storage and feed equipment in a separate room to reduce hazards and dust problems.

2.4 LOCATION OF STRUCTURES: The appropriate regulating authority must be consulted regarding any structure which is so located that normal or flood stream flows may be impeded.

2.5 ELECTRICAL CONTROLS: Main switch gear electrical controls shall be located above grade, in areas not subject to flooding. All electrical work shall conform to the requirements of the National Electrical Code or to relevant state and/or local codes.

2.6 STANDBY POWER: Dedicated Standby power shall be required by the reviewing authority so that water may be treated and/or pumped to the distribution system during power outages to meet the average day demand. Alternatives to dedicated standby power may be considered by the reviewing authority with proper justification. Carbon monoxide detectors are recommended when fuel-fired generators are housed.

2.7 SHOP SPACE AND STORAGE: Adequate facilities should be included for shop space and storage consistent with the designed facilities.

2.8 LABORATORY FACILITIES: Each public water supply shall have its own equipment and facilities for routine laboratory testing necessary to ensure proper operation. Laboratory equipment selection shall be based on the characteristics of the raw water source and the complexity of the treatment process involved. Laboratory test kits which simplify procedures for making one or more tests may be acceptable. An operator or chemist qualified to perform the necessary laboratory tests is essential. Analyses conducted to determine compliance with drinking water regulations must be performed in an appropriately certified laboratory in accordance with Standard Methods for the Examination of Water and Wastewater or

approved alternative methods. Persons designing and equipping laboratory facilities shall confer with the reviewing authority before beginning the preparation of plans or the purchase of equipment. Methods for verifying adequate quality assurances and for routine calibration of equipment should be provided.

2.8.1 Testing equipment: As a minimum, the following laboratory equipment shall be provided:

- a. Surface water supplies shall provide the necessary facilities for microbiological testing of water from both the treatment plant and the distribution system. The reviewing authority may allow deviations from this requirement.
- b. Surface water supplies shall have a nephelometric turbidimeter meeting the requirements of Standard Methods for the Examination of Water and Wastewater.
- c. Each surface water treatment plant utilizing flocculation and sedimentation, including those which lime soften, shall have a pH meter, jar test equipment, and titration equipment for both hardness and alkalinity.
- d. Each ion-exchange softening plant, and lime softening plant treating only groundwater shall have a pH meter and titration equipment for both hardness and alkalinity.
- e. Each iron and/or manganese removal plant shall have test equipment capable of accurately measuring iron to a minimum of 0.1 milligrams per liter, and/or test equipment capable of accurately measuring manganese to a minimum of 0.05 milligrams per liter.
- f. Public water supplies which chlorinate shall have test equipment for determining both free and total chlorine residual by methods in Standard Methods for the Examination of Water and Wastewater.
- g. Public water supplies which fluoridate shall have test equipment for determining fluoride by methods in Standard Methods for the Examination of Water and Wastewater.
- h. Public water supplies which feed poly and/or orthophosphates shall have test equipment capable of accurately measuring phosphates from 0.1 to 20 milligrams per liter.

2.8.2 Physical facilities: Sufficient bench space, adequate ventilation, adequate lighting, storage room, laboratory sink, and auxiliary facilities shall be provided. Air conditioning may be necessary.

2.9 MONITORING EQUIPMENT: Water treatment plants should be provided with equipment (including recorders, where applicable) to monitor the water as follows:

- A. Plants treating surface water and ground water under the direct influence of surface water should have the capability to monitor and record turbidity, free chlorine residual, water temperature and pH at locations necessary to evaluate adequate CT disinfection, and other important process control variables as determined by the reviewing authority. Continuous monitoring and recording may be required.

- B. Plants treating ground water using iron removal and/or ion exchange softening should have the capability to monitor and record free chlorine residual.
- C. Ion exchange plants for nitrate removal should continuously monitor and record the treated water nitrate level.

2.10 SAMPLE TAPS: Sample taps shall be provided so that water samples can be obtained from each water source and from appropriate locations in each unit operation of treatment, and from the finished water. Taps shall be consistent with sampling needs and shall not be of the petcock type. Taps used for obtaining samples for bacteriological analysis shall be of the smooth-nosed type without interior or exterior threads, shall not be of the mixing type, and shall not have a screen, aerator, or other such appurtenance.

2.11 FACILITY WATER SUPPLY: The facility water supply service line and the plant finished water sample tap shall be supplied from a source of finished water at a point where all chemicals have been thoroughly mixed, and the required disinfectant contact time has been achieved (see Section 4.3.2). There shall be no cross-connections between the facility water supply service line and any piping, troughs, tanks, or other treatment units containing wastewater, treatment chemicals, raw or partially treated water.

2.12 WALL CASTINGS: Consideration shall be given to providing extra wall castings built into the structure to facilitate future uses whenever pipes pass through walls of concrete structures.

2.13 METERS: All water supplies shall have an acceptable means of measuring the flow from each source, the washwater, the recycled water, any blended water of different quality, and the finished water.

2.14 PIPING COLOR CODE: To facilitate identification of piping in plants and pumping stations it is recommended that the following color scheme be utilized:

Water Lines

- **Raw or Recycle** Olive Green
- **Settled or Clarified** Aqua
- **Finished or Potable** Dark Blue

Chemical Lines

- **Alum or Primary Coagulant** Orange
- **Ammonia** White
- **Carbon Slurry** Black
- **Caustic** Yellow with Green Band
- **Chlorine (Gas and Solution)** Yellow
- **Chlorine Dioxide** Yellow with Violet Band
- **Fluoride** Light Blue with Red Band
- **Lime Slurry** Light Green
- **Ozone** Yellow with Orange Band

- **Phosphate Compounds** Light Green with Red Band
- **Polymers or Coagulant Aids** Orange with Green Band
- **Potassium Permanganate** Violet
- **Soda Ash** Light Green with Orange Band
- **Sulfuric Acid** Yellow with Red Band
- **Sulfur Dioxide** Light Green with Yellow Band

Waste Lines

- **Backwash Waste** Light Brown
- **Sludge** Dark Brown
- **Sewer (Sanitary or Other)** Dark Gray

Other

- **Compressed Air** Dark Green
- **Gas** Red
- **Other Lines** Light Gray

For liquids or gases not listed above, a unique color scheme and labeling should be used. In situations where two colors do not have sufficient contrast to easily differentiate between them, a six-inch band of contrasting color should be on one of the pipes at approximately 30 inch intervals. The name of the liquid or gas should also be on the pipe. In some cases it may be advantageous to provide arrows indicating the direction of flow.

- 2.15 DISINFECTION:** All wells, pipes, tanks, and equipment which can convey or store potable water shall be disinfected in accordance with current AWWA procedures. Plans or specifications shall outline the procedure and include the disinfectant dosage, contact time, and method of testing the results of the procedure.
- 2.16 OPERATION AND MAINTENANCE MANUAL:** An operation and maintenance manual including a parts list and parts order form, operator safety procedures and an operational trouble-shooting section shall be supplied to the water works as part of any proprietary unit installed in the facility.
- 2.17 OPERATOR INSTRUCTION:** Provisions shall be made for operator instruction at the start-up of a plant or pumping station.
- 2.18 SAFETY:** Consideration must be given to the safety of water plant personnel and visitors. The design must comply with all applicable safety codes and regulations that may include the Uniform Building Code, Uniform Fire Code, National Fire Protection Association Standards, and state and federal OSHA standards. Items to be considered include noise arresters, noise protection, confined space entry, protective equipment and clothing, gas masks, safety showers and eye washes, handrails and guards, warning signs, smoke detectors, toxic gas detectors and fire extinguishers.
- 2.19 SECURITY:** Security measures shall be installed and instituted as required by the reviewing authority. Appropriate design measures to help ensure the security of water system facilities

shall be incorporated. Such measures, as a minimum, shall include means to lock all exterior doorways, windows, gates and other entrances to source, treatment and water storage facilities. Other measures may include fencing, signage, close circuit monitoring, real-time water quality monitoring, and intrusion alarms.

2.20 FLOOD PROTECTION: Other than surface water intakes, all water supply facilities and water treatment plant access roads shall be protected to at least the 100 year flood elevation or maximum flood of record, as required by the reviewing authority. A freeboard factor may also be required by the reviewing authority.

2.21 CHEMICALS AND WATER CONTACT MATERIALS: Chemicals and water contact materials shall be approved by the reviewing authority or meet the appropriate ANSI/AWWA and/or ANSI/NSF standards.

2.22 OTHER CONSIDERATIONS: Consideration must be given to the design requirements of other federal, state, and local regulatory agencies for items such as safety requirements, special designs for the handicapped, plumbing and electrical codes, construction in the flood plain, etc.

PART 3 - SOURCE DEVELOPMENT

3.0 GENERAL: In selecting the source of water to be developed, the designing engineer must prove to the satisfaction of the reviewing authority that an adequate quantity of water will be available, and that the water which is to be delivered to the consumers will meet the current requirements of the reviewing authority with respect to microbiological, physical, chemical and radiological qualities. Each water supply should take its raw water from the best available source which is economically reasonable and technically possible.

3.1 SURFACE WATER: A surface water source includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake. A source water protection plan enacted for continued protection of the watershed from potential sources of contamination shall be provided as determined by the reviewing authority.

3.1.1 Quantity: The quantity of water at the source shall

- a. be adequate to meet the maximum projected water demand of the service area as shown by calculations based on a one in fifty year drought or the extreme drought of record, and should include consideration of multiple year droughts. Requirements for flows downstream of the intake shall comply with requirements of the appropriate reviewing authority,
- b. provide a reasonable surplus for anticipated growth,
- c. be adequate to compensate for all losses such as silting, evaporation, seepage, etc.,
- d. be adequate to provide ample water for other legal users of the source.

3.1.2 Quality: A sanitary survey and study shall be made of the factors, both natural and man made, which may affect water quality. Such survey and study shall include, but not be limited to

- a. determining possible future uses of impoundments or reservoirs,
- b. determining degree of control of watershed by owner,

- c. assessing degree of hazard to the supply by agricultural, industrial, recreational, and residential activities in the watershed, and by accidental spillage of materials that may be toxic, harmful or detrimental to treatment processes,
- d. assessing all waste discharges (point source and non point sources) and activities that could impact the water supply. The location of each waste discharge shall be shown on a scale map,
- e. obtaining samples over a sufficient period of time to assess the microbiological, physical, chemical and radiological characteristics of the water,
- f. assessing the capability of the proposed treatment process to reduce contaminants to applicable standards,
- g. consideration of currents, wind and ice conditions, and the effect of confluencing streams.

3.1.3 Minimum treatment

- a. The design of the water treatment plant must consider the worst conditions that may exist during the life of the facility.
- b. The minimum treatment required shall be determined by the reviewing authority.
- c. Filtration preceded by appropriate pretreatment shall be provided for all surface waters.

Exemptions may be approved by the reviewing authority on a case-by-case basis.

3.1.4 Structures

3.1.4.1 Design of intake structures shall provide for

- a. withdrawal of water from more than one level if quality varies with depth,
- b. separate facilities for release of less desirable water held in storage,
- c. where frazil ice may be a problem, holding the velocity of flow into the intake structure
- d. to a minimum, generally not to exceed 0.5 feet per second,
- e. inspection of manholes every 1000 feet for pipe sizes large enough to permit visual inspection,
- f. occasional cleaning of the inlet line,
- g. adequate protection against rupture by dragging anchors, ice, etc.,
- h. ports located above the bottom of the stream, lake or impoundment, but at sufficient depth to be kept submerged at low water levels,
- i. where shore wells are not provided, a diversion device capable of keeping large quantities of fish or debris from entering an intake structure,
- j. i when buried surface water collectors are used, sufficient intake opening area must be provided to minimize inlet headloss. Particular attention should be given to the selection of backfill material in relation to the

collector pipe slot size and gradation of the native material over the collector system.

3.1.4.2 Raw water pumping wells shall

- a. have motors and electrical controls located above grade, and protected from flooding as required by the reviewing authority
- b. be accessible,
- c. be designed against flotation,
- d. be equipped with removable or traveling screens before the pump suction well,
- e. provide for introduction of chlorine or other chemicals in the raw water transmission main if necessary for quality control,
- f. have intake valves and provisions for backflushing or cleaning by a mechanical device and testing for leaks, where practical,
- g. have provisions for withstanding surges where necessary,

3.1.4.3 An off-stream raw water storage reservoir is a facility into which water is pumped during periods of good quality and high stream flow for future release to treatment facilities. These off-stream raw water storage reservoirs shall be constructed to assure that

- a. water quality is protected by controlling runoff into the reservoir,
- b. dikes are structurally sound and protected against wave action and erosion,
- c. intake structures and devices meet requirements of Section 3.1.4.1,
- d. point of influent flow is separated from the point of withdrawal,
- e. separate pipes are provided for influent to and effluent from the reservoir.

3.1.5 Zebra Mussel Control: If it is determined that chemical treatment is warranted for the control of zebra mussels:

- a. Chemical treatment shall be in accordance with Chapter 5 of the Recommended Standards for Water Works and shall be acceptable to the reviewing authority.
- b. Plant safety items, including but not limited to ventilation, operator protective equipment, eyewashes/showers, cross connection control, etc. shall be provided.
- c. Solution piping and diffusers shall be installed within the intake pipe or in a suitable carrier pipe. Provisions shall be made to prevent dispersal of chemical into the water environment outside the intake. Diffusers shall be located and designed to protect all intake structure components.
- d. A spare solution line should be installed to provide redundancy and to facilitate the use of alternate chemicals.
- e. The chemical feeder shall be interlocked with plant system controls to shut down automatically when the raw water flow stops.

- f. When alternative control methods are proposed for the control of zebra mussels, appropriate piloting or demonstration studies, satisfactory to the reviewing authority, may be required.

3.1.6 Impoundments and reservoirs

3.1.6.1 Site preparation shall provide where applicable

- a. removal of brush and trees to high water elevation,
- b. protection from floods during construction,
- c. abandonment of all wells which will be inundated, in accordance with requirements of the reviewing authority.

3.1.6.2 Construction may require

- a. approval from the appropriate regulatory agencies of the safety features for stability and spillway design,
- b. a permit from an appropriate regulatory agency for controlling stream flow or installing a structure on the bed of a stream or interstate waterway.

3.1.6.3 Water Supply Dams: Water supply dams shall be designed and constructed in accordance with the requirements of the appropriate regulatory agency.

3.1.7 Security: Adequate security should be provided to prevent unauthorized access to vulnerable components. Specific consideration should be given to installation of fencing, locks, surveillance cameras, etc.

3.2 GROUNDWATER: A groundwater source includes all water obtained from dug, drilled, bored or driven wells, and infiltration lines.

3.2.1 Quantity

3.2.1.1 Source capacity: The total developed groundwater source capacity, unless otherwise specified by the reviewing authority, shall equal or exceed the design maximum day demand with the largest producing well out of service.

3.2.1.2 Number of sources: A minimum of two sources of groundwater shall be provided, unless otherwise specified by the reviewing authority. Consideration should be given to locating redundant sources in different aquifers or different locations of an aquifer.

3.2.1.3 Standby power:

- a. To ensure continuous service when the primary power has been interrupted, a standby power supply shall be provided through
 - 1. connection to at least two independent public power sources, or
 - 2. dedicated portable or in-place auxiliary power of adequate supply and connectivity.

- b. When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, the pre-lubrication line shall be provided with a valved by-pass around the automatic control, or the automatic control shall be wired to the emergency power source.

3.2.2 Quality

3.2.2.1 Microbiological quality:

- a. After disinfection of each new, modified or reconditioned groundwater source, one or more water samples shall be submitted to a laboratory satisfactory to the reviewing authority for microbiological analysis with satisfactory results reported to such agency prior to placing the well into service.
- b. A ground water under the direct influence of surface water determination acceptable to the reviewing authority shall be provided for all new wells.

3.2.2.2 Physical, chemical and radiological characteristics

- a. Every new, modified or reconditioned groundwater source shall be examined for applicable physical, chemical and radiological characteristics as required by the reviewing authority by tests of a representative sample in a laboratory satisfactory to the reviewing authority, with results reported to such authority.
- b. Samples shall be collected at the conclusion of the test pumping procedure and examined as soon as practical.
- c. Field determinations of physical and chemical constituents or special sampling procedures may be required by the reviewing authority.

3.2.3 Location

3.2.3.1 Well location: The reviewing authority shall be consulted prior to design and construction regarding a proposed well location as it relates to required separation between existing and potential sources of contamination and groundwater development. The well location should be selected to minimize the impact on other wells and other water resources.

3.2.3.2 Continued sanitary protection: Continued sanitary protection of the well site from potential sources of contamination shall be provided either through ownership, zoning, easements, leasing or other means acceptable to the reviewing authority. Fencing of the site may be required by the reviewing authority.

3.2.3.3 Wellhead protection: A wellhead protection plan for continued protection of the wellhead from potential sources of contamination shall be provided as determined by the reviewing authority.

3.2.4 Testing and records

3.2.4.1 Yield and drawdown tests

- a. A yield and drawdown test shall be conducted in accordance with a protocol pre-approved by the reviewing authority.
- b. The test shall be performed on every production well after construction or subsequent treatment and prior to placement of the permanent pump.
- c. The test methods shall be clearly indicated in the project specifications.
- d. The test pump should have a capacity at least 1.5 times the flow anticipated at maximum anticipated drawdown.
- e. The test shall provide, as a minimum, for continuous pumping for at least 24 hours at the design pumping rate or until stabilized drawdown has continued for at least six hours when test pumped at 1.5 times the design pumping rate, or as required by the reviewing authority.
- f. The following data shall be submitted to the reviewing authority:
 1. test pump capacity-head characteristics,
 2. static water level,
 3. depth of test pump setting,
 4. time of starting and ending each test cycle, and
 5. the zone of influence for the well or wells.
- g. A report shall be submitted which provides recordings and graphic evaluation of the following at one hour intervals or less as may be required by the reviewing authority:
 1. pumping rate,
 2. pumping water level,
 3. drawdown, and
 4. water recovery rate and levels.
- h. At the discretion of the reviewing authority, more comprehensive testing may be required.

3.2.4.2 Plumbness and alignment requirements

- a. Every well shall be tested for plumbness and alignment in accordance with AWWA standards.
- b. The test method and allowable tolerance shall be clearly stated in the specifications.
- c. If the well fails to meet these requirements, it may be accepted by the engineer if it does not interfere with the installation or operation of the pump or uniform placement of grout.

3.2.4.3 Geological data shall

- a. be determined from samples collected at 5-foot intervals and at each pronounced change in formation,

- b. be recorded and samples submitted to the appropriate authority,
- c. be supplemented with a driller=s log, accurate geographical location such as latitude and longitude or GIS coordinates, and other information on accurate records of drillhole diameters and depths, assembled order of size and length of casing, screens and liners, grouting depths, formations penetrated, water levels, and location of any blast charges.

3.2.4.4 Retention of records: The owner of each well shall retain all records pertaining to each well, until the well has been properly abandoned.

3.2.5 General well construction

3.2.5.1 Drilling fluids and additives shall

- a. not impart any toxic substances to the water or promote bacterial contamination,
- b. be acceptable to the reviewing authority.

3.2.5.2 Minimum protected depths: Minimum protected depths of drilled wells shall provide watertight construction to such depth as may be required by the reviewing authority, to

- a. exclude contamination, and
- b. seal off formations that are, or may be, contaminated or yield undesirable water.

3.2.5.3 Temporary steel casing: Temporary steel casing used for construction shall be capable of withstanding the structural load imposed during its installation and removal.

3.2.5.4 Permanent steel casing pipe shall:

- a. be new single steel casing pipe meeting AWWA Standard A-100, ASTM or API specifications for water well construction,
- b. have minimum weights and thickness indicated in Table I,
- c. have additional thickness and weight if minimum thickness is not considered sufficient to assure reasonable life expectancy of a well,
- d. be capable of withstanding forces to which it is subjected,
- e. be equipped with a drive shoe when driven, and
- f. have full circumferential welds or threaded coupling joints.

3.2.5.5 Polyvinyl chloride plastic (PVC) well casing: The reviewing authority may approve the use of PVC casing for all or for limited applications. Where approved, PVC casing, as a minimum,

- a. shall be new pipe meeting ASTM F480 and ANSI/NSF Standard 61 and be appropriately marked;

- b. shall have a minimum wall thickness equivalent to SDR (standard dimension ratio) 21; however, diameters of 8 inches or greater or deep wells may require greater thickness to meet collapse strength requirements;
- c. shall not be used at sites where permeation by hydrocarbons or degradation may occur;
- d. shall be properly stored in a clean area free from exposure to direct sunlight;
- e. shall be assembled using couplings or solvent welded joints; all couplings and solvents shall meet ANSI/NSF Standard 14, ASTM F480, or similar requirements; and
- f. shall not be driven.

3.2.5.6 Other nonferrous casing materials

- a. Approval of the use of any nonferrous material as well casing shall be subject to special determination by the reviewing authority prior to submission of plans and specifications.
- b. Nonferrous material proposed as a well casing must be resistant to the corrosiveness of the water and to the stresses to which it will be subjected during installation, grouting and operation.

3.2.5.7 Packers: Packers shall be of material that will not impart taste, odor, toxic substances or bacterial contamination to the well water. Lead packers shall not be used.

3.2.5.8 Screens shall

- a. be constructed of materials resistant to damage by chemical action of groundwater or cleaning operations,
- b. have size of openings based on sieve analysis of formation and/or gravel pack materials,
- c. have sufficient length and diameter to provide adequate specific capacity and low aperture entrance velocity. Usually the entrance velocity should not exceed 0.1 feet per second,
- d. be installed so that the pumping water level remains above the screen under all operating conditions,
- e. where applicable, be designed and installed to permit removal or replacement without adversely affecting water-tight construction of the well, and
- f. be provided with a bottom plate or washdown bottom fitting of the same material as the screen.

3.2.5.9 Grouting requirements: All permanent well casing shall be surrounded by a minimum of 1 1/2 inches of grout to the depth required by the review authority. Other forms of grouting may be approved for driven casing. All temporary

construction casings shall be removed. Where removal is not possible or practical, the casing shall be withdrawn at least five feet to ensure grout contact with the native formation.

a. Neat cement grout

1. Cement conforming to AWWA A100, and water, with not more than six gallons of water per 94 pounds of cement, must be used for 1 1/2 inch openings.
2. Additives may be used to increase fluidity subject to approval by the reviewing authority.

b. Concrete grout

1. Equal parts of cement conforming to AWWA A100, and sand, with not more than six gallons of water per 94 pounds of cement may be used for openings larger than 1½ inches.
2. Where an annular opening larger than four inches is available, gravel not larger than one-half inch in size may be added.

c. Bentonite: where allowed by the reviewing authority. This is a mixture of water and commercial sodium-bentonite clay manufactured for the purpose of water well grouting. Bentonite mixtures shall contain no less than 20 percent bentonite solids. Organic polymers used in the grout mixtures must meet ANSI/NSF Standard 60.

d. Clay seal: Where an annular opening greater than six inches is available a clay seal of clean local clay mixed with at least 10 per cent swelling bentonite may be used when approved by the reviewing authority.

e. Application

1. Sufficient annular opening shall be provided to permit a minimum of 1½ inches of grout around permanent casings, including couplings.
2. Prior to grouting through creviced or fractured formations, bentonite or similar materials may be added to the annular opening, in the manner indicated for grouting.
3. When the annular opening is less than four inches, grout shall be installed under pressure by means of a grout pump from the bottom of the annular opening upward in one continuous operation until the annular opening is filled.
4. When the annular opening is four or more inches and less than 100 feet in depth, and concrete grout is used, it may be placed by gravity through a grout pipe installed to the bottom of the annular opening in one continuous operation until the annular opening is filled.
5. When the annular opening exceeds six inches, is less than 100 feet in depth, and a clay seal is used, it may be placed by gravity.
6. After cement grouting is applied, work on the well shall be discontinued until the cement or concrete grout has properly set.

7. Grout placement must be sufficient to achieve proper density or percent solids throughout the annular space.

f. **Guides:** The casing must be provided with sufficient guides welded to the casing to permit unobstructed flow and uniform thickness of grout.

3.2.5.10 Upper terminal well construction

- a. Permanent casing for all groundwater sources shall project at least 12 inches above the pumphouse floor or concrete apron surface and at least 18 inches above final ground surface.
- b. Where a well house is constructed, the floor surface shall be at least six inches above the final ground elevation.
- c. Sites subject to flooding shall be provided with an earth mound to raise the pumphouse floor to an elevation at least two feet above the highest known flood elevation, or other suitable protection as determined by the reviewing authority.
- d. The top of the well casing at sites subject to flooding shall terminate at least three feet above the 100 year flood level or the highest known flood elevation, whichever is higher, or as the reviewing authority directs.
- e. Protection from physical damage shall be provided as required by the reviewing authority.

3.2.5.11 Development

- a. Every well shall be developed to remove the native silts and clays, drilling mud or finer fraction of the gravel pack.
- b. Development should continue until the maximum specific capacity is obtained from the completed well.
- c. Where chemical conditioning is required, the specifications shall include provisions for the method, equipment, chemicals, testing for residual chemicals, and disposal of waste and inhibitors.
- d. Where blasting procedures may be used, the specifications shall include the provisions for blasting and cleaning. Special attention shall be given to assure that the grouting and casing are not damaged by the blasting.

3.2.5.12 Disinfection of every groundwater source

- a. shall be provided after completion of work, if a substantial period elapses prior to test pumping or placement of permanent pumping equipment, and
- b. shall be provided after placement of permanent pumping equipment.
- c. shall be done in accordance with AWWA C654 or method approved by the reviewing authority.

3.2.5.13 Capping requirements

- a. A welded metal plate or a threaded cap is the preferred method for capping a well. All well caps, temporary or permanent, shall be effectively located/sealed against the entrance of water and contaminants.
- b. At all times during the progress of work, the contractor shall provide protection to prevent tampering with the well or entrance of foreign materials.

3.2.5.14 Well abandonment

- a. Test wells and groundwater sources which are not in use shall be sealed by such methods as necessary to restore the controlling geological conditions which existed prior to construction or as directed by the appropriate regulatory agency.
- b. Wells to be abandoned shall
 1. be sealed to prevent undesirable exchange of water from one aquifer to another,
 2. preferably be filled with neat cement grout,
 3. have fill materials other than cement grout or concrete, disinfected and free of foreign materials, and
 4. when filled with cement grout or concrete, these materials shall be applied to the well hole through a pipe, tremie, or bailer.

3.2.6 Aquifer types and construction methods — Special conditions

3.2.6.1 Sand or gravel wells

- a. If clay or hard pan is encountered above the water bearing formation, the permanent casing and grout shall extend through such materials.
- b. If a sand or gravel aquifer is overlaid only by permeable soils the permanent casing and grout shall extend to at least 25 feet below original or final ground elevation, whichever is lower. Excavation of topsoil around the well casing should be avoided.
- c. If a temporary outer casing is used, it shall be completely withdrawn as grout is applied.

3.2.6.2 Gravel pack wells

- a. Gravel pack shall be well rounded particles, 95 per cent siliceous material, that are smooth and uniform, free of foreign material, properly sized, washed and then disinfected immediately prior to or during placement.
- b. Gravel pack shall be placed in one uniform continuous operation.
- c. Gravel refill pipes, when used, shall be Schedule 40 steel pipe incorporated within the pump foundation and terminated with screwed or welded caps at least 12 inches above the pump house floor or concrete apron.
- d. Gravel refill pipes located in the grouted annular opening shall be surrounded by a minimum of 1 1/2 inches of grout.

- e. Protection from leakage of grout into the gravel pack or screen shall be provided.
- f. Permanent inner and outer casings shall meet requirements of Section 3.2.5.4.
- g. Minimum casing and grouted depth shall be acceptable to the reviewing authority.

3.2.6.3 Radial water collector

- a. Locations of all caisson construction joints and porthole assemblies shall be indicated.
- b. The caisson wall shall be reinforced to withstand the forces to which it will be subjected.
- c. Radial collectors shall be in areas and at depths approved by the reviewing authority.
- d. Provisions shall be made to assure that radial collectors are essentially horizontal.
- e. The top of the caisson shall be covered with a watertight floor.
- f. All openings in the floor shall be curbed and protected from entrance of foreign material.
- g. The pump discharge piping shall not be placed through the caisson walls. In unique situations where this is not feasible, a water tight seal must be obtained at the wall.

3.2.6.4 Infiltration lines

- a. Infiltration lines should be considered only where geological conditions preclude the possibility of developing an acceptable drilled well.
- b. The area around infiltration lines shall be under the control of the water purveyor for a distance acceptable to or required by the reviewing authority.
- c. Flow in the lines shall be by gravity to the collecting well.
- d. Water from infiltration lines shall be considered as groundwater under the direct influence of surface water unless demonstrated otherwise.

3.2.6.5 Limestone or sandstone wells

- a. Where the depth of unconsolidated formations is more than 50 feet, the permanent casing shall be firmly seated in uncreviced or unbroken rock. Grouting requirements shall be determined by the reviewing authority.
- b. Where the depth of unconsolidated formations is less than 50 feet, the depth of casing and grout shall be at least 50 feet or as determined by the reviewing authority.

3.2.6.6 Naturally flowing wells

- a. Shall require special consideration by the reviewing authority where there is an absence of an impervious confining layer.
- b. Flow shall be controlled. Overflows shall discharge at least 18 inches above grade and flood level, and be visible. Discharge shall be to an effective drainage structure.
- c. Permanent casing and grout shall be provided.
- d. If erosion of the confining bed appears likely, special protective construction may be required by the reviewing authority.

3.2.7 Well pumps, discharge piping and appurtenances

3.2.7.1 Line shaft pumps: Wells equipped with line shaft pumps shall

- a. have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least one-half inch into the pump base,
- b. have the pump foundation and base designed to prevent water from coming into contact with the joint, and
- c. avoid the use of oil lubrication at pump settings less than 400 feet. Lubricants must meet ANSI/NSF Standard 61 or be approved by the reviewing authority.

3.2.7.2 Submersible pumps: Where a submersible pump is used

- a. the top of the casing shall be effectively sealed against the entrance of water under all conditions of vibration or movement of conductors or cables, and
- b. the electrical cable shall be firmly attached to the riser pipe at 20 foot intervals or less.

3.2.7.3 Discharge piping

a. The discharge piping shall

1. be designed so that the friction loss will be low,
2. have control valves and appurtenances located above the pumphouse floor when an above-ground discharge is provided,
3. be protected against the entrance of contamination,
4. be equipped with a check valve in or at the well, a shutoff valve, a pressure gauge, a means of measuring flow, and a smooth nosed sampling tap located at a point where positive pressure is maintained,
5. where applicable, be equipped with an air release-vacuum relief valve located upstream from the check valve, with exhaust/relief piping terminating in a down-turned position at least 18 inches above the floor and covered with a 24 mesh corrosion resistant screen,
6. be valved to permit test pumping and control of each well,

7. have all exposed piping, valves and appurtenances protected against physical damage and freezing,
8. be properly anchored to prevent movement, and
9. be protected against surge or water hammer.
10. The discharge piping should be provided with a means of pumping to waste, but shall not be directly connected to a sewer.

3.2.7.4 Pitless well units

- a. The reviewing authority must be contacted for approval of specific applications of pitless units.
- b. Pitless units shall
 1. be shop-fabricated from the point of connection with the well casing to the unit cap or cover,
 2. be threaded or welded to the well casing,
 3. be of watertight construction throughout,
 4. be of materials and weight at least equivalent and compatible to the casing,
 5. have field connection to the lateral discharge from the pitless unit of threaded, flanged or mechanical joint connection, and
 6. terminate at least 18 inches above final ground elevation or three feet above the 100 year flood level or the highest known flood elevation, whichever is higher, or as the reviewing authority directs.
- c. The design of the pitless unit shall make provision for
 1. access to disinfect the well,
 2. a properly constructed casing vent meeting the requirements of Section 3.2.7.6, 3. facilities to measure water levels in the well (see Section 3.2.7.7),
 3. a cover at the upper terminal of the well that will prevent the entrance of contamination,
 4. a contamination-proof entrance connection for electrical cable,
 5. an inside diameter as great as that of the well casing, up to and including casing diameters of 12 inches, to facilitate work and repair on the well, pump, or well screen, and
 6. at least one check valve within the well casing or in compliance with requirements of the reviewing authority.
- d. If the connection to the casing is by field weld, the shop-assembled unit must be designed specifically for field welding to the casing. The only field welding permitted will be that needed to connect a pitless unit to the casing.

3.2.7.5 Pitless Adapters: Pitless adapters may be acceptable at the discretion of the reviewing authority. The use of any pitless adapter must be pre-approved by the reviewing authority.

3.2.7.6 Casing vent: Provisions shall be made for venting the well casing to atmosphere. The vent shall terminate in a downturned position, at or above the top of the casing or pitless unit, no less than 12 inches above grade or floor, in a minimum 1½ inch diameter opening covered with a 24 mesh, corrosion resistant screen. The pipe connecting the casing to the vent shall be of adequate size to provide rapid venting of the casing. Where vertical turbine pumps are used, vents into the side of the casing may be necessary to provide adequate well venting; installation of these vents shall be in accordance with the requirements of the reviewing authority.

3.2.7.7 Water level measurement

- a. Provisions shall be made for periodic measurement of water levels in the completed well.
- b. Where pneumatic water level measuring equipment is used it shall be made using corrosion resistant materials attached firmly to the drop pipe or pump column and in such a manner as to prevent entrance of foreign materials.

3.2.7.8 Observation wells shall be

- a. constructed in accordance with the requirements for permanent wells if they are to remain in service after completion of a water supply well, and
- b. protected at the upper terminal to preclude entrance of foreign materials.

PART 4 - TREATMENT

4.0 GENERAL: The design of treatment processes and devices shall depend on evaluation of the nature and quality of the particular water to be treated, seasonal variations, the desired quality of the finished water and the mode of operation planned.

4.1 Clarification: Clarification is generally considered to consist of any process or combination of processes which reduces the concentration of suspended matter in drinking water prior to filtration. Plants designed to reduce suspended solids concentrations prior to filtration shall

- a. provide a minimum of two units each for coagulation, flocculation and solids removal,
- b. permit operation of the units either in series or parallel where softening is performed and should permit series or parallel operation where plain clarification is performed,
- c. be constructed to permit units to be taken out of service without disrupting operation, and with drains or pumps sized to
- d. allow dewatering in a reasonable period of time,
- e. provide multiple-stage treatment facilities when required by the reviewing authority,
- f. be started manually following shutdown,

- g. minimize hydraulic head losses between units to allow future changes in processes without the need for repumping.

4.1.1 Presedimentation: Waters containing high turbidity may require pretreatment, usually sedimentation either with or without the addition of coagulation chemicals.

- a. **Basin design** – Presedimentation basins should have hopper bottoms or be equipped with continuous mechanical sludge removal apparatus, and provide arrangements for dewatering.
- b. **Inlet** – Incoming water shall be dispersed across the full width of the line of travel as quickly as possible; short-circuiting must be prevented.
- c. **Bypass** – Provisions for bypassing presedimentation basins shall be included.
- d. **Detention time** – Three hours detention is the minimum period recommended; greater detention may be required.

4.1.2 Coagulation: Coagulation shall mean a process using coagulant chemicals and mixing by which colloidal and suspended material are destabilized and agglomerated into settleable or filterable flocs, or both. The engineer shall submit the design basis for the velocity gradient (G value) selected, considering the chemicals to be added and water temperature, color and other related water quality parameters. For surface water plants using direct or conventional filtration, the use of a primary coagulant is required at all times

- a. **Mixing** – The detention period should not be more than thirty seconds with mixing equipment capable of imparting a minimum velocity gradient (G) of at least 750 fps/ft. The design engineer should determine the appropriate G value and detention time through jar testing.
- b. **Equipment** – Basins should be equipped with devices capable of providing adequate mixing for all treatment flow rates. Static mixing may be considered where the flow is relatively constant and will be high enough to maintain the necessary turbulence for complete chemical reactions.
- c. **Location** – The coagulation and flocculation basins shall be as close together as possible.

4.1.3 Flocculation: Flocculation shall mean a process to enhance agglomeration or collection of smaller floc particles into larger, more easily settleable or filterable particles through gentle stirring by hydraulic or mechanical means.

- a. **Basin Design** – Inlet and outlet design shall minimize short-circuiting and destruction of floc. Series compartments are recommended to further minimize short-circuiting and to provide decreasing mixing energy with time. Basins shall be designed so that individual basins may be isolated without disrupting plant operation. A drain and/or pumps shall be provided to handle dewatering and sludge removal.
- b. **Detention** – The detention time for floc formation should be at least 30 minutes with consideration to using tapered (i.e., diminishing velocity gradient) flocculation.

The flow-through velocity should be not less than 0.5 nor greater than 1.5 feet per minute.

- c. **Equipment** – Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 3.0 feet per second. External, non-submerged motors are preferred.
- d. **Piping** – Flocculation and sedimentation basins shall be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins shall be not less than 0.5 nor greater than 1.5 feet per second. Allowances must be made to minimize turbulence at bends and changes in direction.
- e. **Other designs** – Baffling may be used to provide for flocculation in small plants only after consultation with the reviewing authority. The design should be such that the velocities and flows noted above will be maintained.
- f. **Superstructure** – A superstructure over the flocculation basins may be required.

4.1.4 Sedimentation: Sedimentation shall follow flocculation unless otherwise approved by the reviewing agency. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to conventional gravity sedimentation units:

- a. **Detention time** – shall provide a minimum of four hours of settling time. This may be reduced to two hours for lime-soda softening facilities treating only groundwater. Reduced sedimentation time may also be approved when equivalent effective settling is demonstrated or when overflow rate is not more than 0.5 gpm per square foot (1.2 m/hr).
- b. **Inlet devices** – Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. A baffle should be constructed across the basin close to the inlet end and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin.
- c. **Outlet devices** – Outlet weirs or submerged orifices shall maintain velocities suitable for settling in the basin and minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow. Outlet weirs and submerged orifices shall be designed as follows:
 - 1. The rate of flow over the outlet weirs or through the submerged orifices shall not exceed 20,000 gallons per day per foot (250 m³/day/m) of the outlet launder.
 - 2. Submerged orifices should not be located lower than three (3) feet below the flow line.
 - 3. The entrance velocity through the submerged orifices shall not exceed 0.5 feet per second.
- d. **Velocity** – The velocity through settling basins should not exceed 0.5 feet per minute. The basins must be designed to minimize short-circuiting. Fixed or

adjustable baffles must be provided as necessary to achieve the maximum potential for clarification.

- e. **Overflow** – An overflow weir or pipe designed to establish the maximum water level desired on top of the filters should be provided. The overflow shall discharge by gravity with a free fall at a location where the discharge will be noted.
- f. **Superstructure** – A superstructure over the sedimentation basins may be required. If there is no mechanical equipment in the basins and if provisions are included for adequate monitoring under all expected weather conditions, a cover may be provided in lieu of a superstructure.
- g. **Drainage** – Basins must be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than one foot in twelve feet where mechanical sludge collection equipment is not required.
- h. **Flushing lines** – Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to the reviewing authority.
- i. **Safety** – Permanent ladders or handholds should be provided on the inside walls of basins above the water level. Guard rails should be included. Compliance with other applicable safety requirements, such as OSHA, shall be required.
- j. **Sludge collection system** - shall be designed to ensure the collection of sludge from throughout the basin.
- k. **Sludge removal** – Sludge removal design shall provide that
 1. sludge pipes shall be not less than three inches in diameter and so arranged as to facilitate cleaning,
 2. entrance to sludge withdrawal piping shall prevent clogging,
 3. valves shall be located outside the tank for accessibility,
 4. the operator may observe and sample sludge being withdrawn from the unit.
- l. **Sludge disposal** – Facilities are required by the reviewing authority for disposal of sludge. (see Part 9).

4.1.5 Solids contact unit: Units are generally acceptable for combined softening and clarification where water characteristics, especially temperature, do not fluctuate rapidly, flow rates are uniform and operation is continuous. Before such units are considered as clarifiers without softening, specific approval of the reviewing authority shall be obtained. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flow which are less than the design rate and for changes in water characteristics. A minimum of two units are required for surface water treatment.

- 4.1.5.1 Installation of equipment:** Supervision by a representative of the manufacturer shall be provided with regard to all mechanical equipment at the time of
- a. installation, and

- b. initial operation.

4.1.5.2 Operating equipment: The following shall be provided for plant operation:

- a. a complete outfit of tools and accessories,
- b. necessary laboratory equipment,
- c. adequate piping with suitable sampling taps located to permit the collection of samples of water from critical portions of the units.

4.1.5.3 Chemical feed: Chemicals shall be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water.

4.1.5.4 Mixing: A rapid mix device or chamber ahead of solids contact units may be required by the reviewing authority to assure proper mixing of the chemicals applied. Mixing devices employed shall be so constructed as to

- a. provide good mixing of the raw water with previously formed sludge particles, and
- b. prevent deposition of solids in the mixing zone.

4.1.5.5 Flocculation: Flocculation equipment

- a. shall be adjustable (speed and/or pitch),
- b. must provide for coagulation in a separate chamber or baffled zone within the unit,
- c. should provide that the flocculation and mixing period to be not less than 30 minutes.

4.1.5.6 Sludge concentrators

- a. The equipment should provide either internal or external concentrators in order to obtain a concentrated sludge with a minimum of waste water.
- b. Large basins should have at least two sumps for collecting sludge located in the central flocculation zone.

4.1.5.7 Sludge removal: Sludge removal design shall provide that

- a. sludge pipes shall be not less than three inches in diameter and so arranged as to facilitate cleaning,
- b. entrance to sludge withdrawal piping shall prevent clogging,
- c. valves shall be located outside the tank for accessibility, and
- d. the operator may observe and sample sludge being withdrawn from the unit.

4.1.5.8 Cross-connections

- a. Blow-off outlets and drains must terminate and discharge at places satisfactory to the reviewing authority.
- b. Cross-connection control must be included for the potable water lines used to backflush sludge lines.

4.1.5.9 Detention period: The detention time shall be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit. Based on design flow rates, the detention time should be

- a. two to four hours for suspended solids contact clarifiers and softeners treating surface water, and
- b. one to two hours for the suspended solids contact softeners treating only groundwater.
- c. The reviewing authority may alter detention time requirements.

4.1.5.10 Suspended slurry concentrate: Softening units should be designed so that continuous slurry concentrates of one per cent or more, by weight, can be satisfactorily maintained.

4.1.5.11 Water losses

- a. Units shall be provided with suitable controls for sludge withdrawal.
- b. Total water losses should not exceed
 1. five per cent for clarifiers,
 2. three per cent for softening units.
- c. Solids concentration of sludge bled to waste should be
 1. three per cent by weight for clarifiers,
 2. five per cent by weight for softeners.

4.1.5.12 Weirs or orifices: The units should be equipped with either overflow weirs or orifices constructed so that water at the surface of the unit does not travel over 10 feet horizontally to the collection trough.

- a. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank.
- b. Weir loading shall not exceed
 1. 10 gpm per foot of weir length (120 L/min/m) for units used for clarifiers,
 2. 20 gpm per foot of weir length (240 L/min/m) for units used for softeners.
- c. Where orifices are used the loading rates per foot of launder rates should be equivalent to weir loadings. Either shall produce uniform rising rates over the entire area of the tank.

4.1.5.13 Upflow rates: Unless supporting data is submitted to the reviewing authority to justify rates exceeding the following, rates shall not exceed

- a. 1.0 gpm per square foot of area (2.4 m/hr) at the sludge separation line for units used for clarifiers,
- b. 1.75 gpm per square foot of area (4.2 m/hr) at the slurry separation line, for units used for softeners.

4.1.6 Tube or plate settlers: Proposals for settler unit clarification must include pilot plant and/or full scale demonstration data on water with similar quality prior to the preparation of final plans and specifications for approval. Settler units consisting of variously shaped tubes or plates which are installed in multiple layers and at an angle to the flow may be used for sedimentation, following flocculation.

4.1.6.1 General criteria

- a. **Inlet and outlet considerations** -- Design to maintain velocities suitable for settling in the basin and to minimize short-circuiting. Plate units shall be designed to minimize maldistribution across the units.
- b. **Drainage** -- Drain piping from the settler units must be sized to facilitate a quick flush of the settler units and to prevent flooding other portions of the plant.
- c. **Protection from freezing** -- Although most units will be located within a plant, outdoor installations must provide sufficient freeboard above the top of settlers to prevent freezing in the units. A cover or enclosure is strongly recommended.
- d. **Application rate for tubes** -- A maximum rate of 2 gpm per square foot of cross-sectional area (4.8 m/hr) for tube settlers, unless higher rates are successfully shown through pilot plant or in-plant demonstration studies.
- e. **Application rates for plates** -- A maximum plate loading rate of 0.5 gpm per square foot (1.2 m/hr), based on 80 percent of the projected horizontal plate area.
- f. **Flushing lines**-- Flushing lines shall be provided to facilitate maintenance and must be properly protected against backflow or back siphonage.
- g. **Placement modules should be placed:**
 1. In zones of stable hydraulic conditions.
 2. In areas nearest effluent launders for basins not completely covered by the modules.
- h. **Inlets and Outlets:** Inlets and outlets shall conform with Sections 4.1.4.b and 4.1.4.c.
- i. **Support:** The support system should be able to carry the weight of the modules when the basin is drained plus any additional weight to support maintenance.
- j. Provisions should be made to allow the water level to be dropped, and a water or an air jet system for cleaning the modules.

4.1.7 High rate clarification processes: High rate clarification processes may be approved upon demonstrating satisfactory performance under on-site pilot plant conditions or documentation of full scale plant operation with similar raw water quality conditions as

allowed by the reviewing authority. Reductions in detention times and/or increases in weir loading rates shall be justified. Examples of such processes may include dissolved air flotation, ballasted flocculation, contact flocculation/clarification, and helical upflow, solids contact units.

4.2 FILTRATION: Acceptable filters shall include, upon the discretion of the reviewing authority, the following types:

- A. rapid rate gravity filters (4.2.1),
- B. rapid rate pressure filters (4.2.2),
- C. diatomaceous earth filtration (4.2.3),
- D. slow sand filtration (4.2.4),
- E. direct filtration (4.2.5),
- F. deep bed rapid rate gravity filters (4.2.6),
- G. biologically active filters (4.2.7),
- H. membrane filtration (see Interim Standard on Membrane Technologies), and
- I. bag and cartridge filters (see policy statement on Bag and Cartridge Filters for Public Water Systems).

The application of any one type must be supported by water quality data representing a reasonable period of time to characterize the variations in water quality. Pilot treatment studies may be required to demonstrate the applicability of the method of filtration proposed.

4.2.1 Rapid rate gravity filters

4.2.1.1 Pretreatment: The use of rapid rate gravity filters shall require pretreatment.

4.2.1.2 Rate of filtration: The rate of filtration shall be determined through consideration of such factors as raw water quality, degree of pretreatment provided, filter media, water quality control parameters, competency of operating personnel, and other factors as required by the reviewing authority. Typical filtration rates are from 2 to 4 gpm/ft². In any case, the filter rate must be proposed and justified by the design engineer to the satisfaction of the reviewing authority prior to the preparation of final plans and specifications.

4.2.1.3 Number: At least two units shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service. Where declining rate filtration is provided, the variable aspect of filtration rates, and the number of filters must be considered when determining the design capacity for the filters.

4.2.1.4 Structural details and hydraulics: The filter structure shall be designed to provide for

- a. vertical walls within the filter,
- b. no protrusion of the filter walls into the filter media,
- c. cover by superstructure,
- d. head room to permit normal inspection and operation,
- e. minimum depth of filter box of 8.5 feet,
- f. minimum water depth over the surface of the filter media of three feet,
- g. trapped effluent to prevent backflow of air to the bottom of the filters,
- h. prevention of floor drainage to the filter with a minimum 4-inch curb around the filters,
- i. prevention of flooding by providing overflow,
- j. maximum velocity of treated water in pipe and conduits to filters of two feet per second,
- k. cleanouts and straight alignment for influent pipes or conduits where solids loading is heavy, or following lime-soda softening,
- l. washwater drain capacity to carry maximum flow,
- m. walkways around filters, to be not less than 24 inches wide,
- n. safety handrails or walls around all filter walkways,
- o. construction to prevent cross connections and common walls between potable and non-potable water.

4.2.1.5 Washwater troughs: Washwater troughs should be constructed to have

- a. the bottom elevation above the maximum level of expanded media during washing,
- b. a two-inch freeboard at the maximum rate of wash,
- c. the top edge level and all at the same elevation,
- d. spacing so that each trough serves the same number of square feet of filter area,
- e. maximum horizontal travel of suspended particles to reach the trough not to exceed three feet.

4.2.1.6 Filter material: The media shall be clean silica sand or other natural or synthetic media free from detrimental chemical or bacterial contaminants, approved by the reviewing authority, and having the following characteristics:

- a. a total depth of not less than 24 inches and generally not more than 30 inches,

- b. a uniformity coefficient of the smallest material not greater than 1.65,
- c. a minimum of 12 inches of media with an effective size range no greater than 0.45 mm to 0.55 mm
- d. Types of filter media:
 - 1. **Anthracite** - Filter anthracite shall consist of hard, durable anthracite coal particles of various sizes. Blending of non-anthracite material is not acceptable. Anthracite shall have an
 - a. effective size of 0.45 mm – 0.55 mm with uniformity coefficient not greater than 1.65 when used alone,
 - b. effective size of 0.8 mm – 1.2 mm with a uniformity coefficient not greater than 1.7 when used as a cap,
 - c. effective size for anthracite used as a single media on potable groundwater for iron and manganese removal only shall be a maximum of 0.8 mm (effective sizes greater than 0.8 mm may be approved based upon onsite pilot plant studies or other demonstration acceptable to the reviewing authority).
 - d. specific gravity greater than 1.4,
 - e. acid solubility less than 5 percent,
 - f. A Mho's scale of hardness greater than 2.7.
 - 2. **Sand** – sand shall have
 - a. an effective size of 0.45 mm to 0.55 mm,
 - b. a uniformity coefficient of not greater than 1.65.
 - c. a specific gravity greater than 2.5.
 - d. an acid solubility less than 5 percent.
 - 3. **High Density Sand:** High density sand shall consist of hard durable, and dense grain garnet, ilmenite, hematite, magnetite, or associated minerals of those ores that will resist degradation during handling and use, and shall
 - a. contain at least 95 percent of the associated material with a specific gravity of 3.8 or higher.
 - b. have an effective size of 0.2 to 0.3 mm.
 - c. have a uniformity coefficient of not greater than 1.65.
 - d. have an acid solubility less than 5 percent.
 - 4. **Granular activated carbon (GAC)** – Granular activated carbon as a single media may be considered for filtration only after pilot or full scale testing and with prior approval of the reviewing authority. The design shall include the following:

- a. The media must meet the basic specifications for filter media as given in Section 4.2.1.6.a through c.
 - b. There must be provisions for a free chlorine residual and adequate contact time in the water following the filters and prior to distribution (See 4.3.2.d and 4.3.3).
 - c. There must be means for periodic treatment of filter material for control of bacterial and other growth.
 - d. Provisions must be made for frequent replacement or regeneration.
5. Other media types or characteristics may be considered based on experimental data and operating experience.

e. Support media

1. **Torpedo sand** – A three-inch layer of torpedo sand shall be used as a supporting media for filter sand where supporting gravel is used, and shall have
 - a. effective size of 0.8 mm to 2.0 mm, and
 - b. uniformity coefficient not greater than 1.7.
2. **Gravel** – Gravel, when used as the supporting media shall consist of cleaned and washed, hard, durable, rounded silica particles and shall not include flat or elongated particles. The coarsest gravel shall be 2.5 inches in size when the gravel rests directly on a lateral system, and must extend above the top of the perforated laterals. Not less than four layers of gravel shall be provided in accordance with the following size and depth distribution:

Size Depth

- 3/32 to 3/16 inches 2 to 3 inches
- 3/16 to 1/2 inches 2 to 3 inches
- 1/2 to 3/4 inches 3 to 5 inches
- 3/4 to 1 ½ inches 3 to 5 inches
- 1 ½ to 2 ½ inches 5 to 8 inches

Reduction of gravel depths and other size gradations may be considered upon justification to the reviewing authority for slow sand filtration or when proprietary filter bottoms are specified.

4.2.1.7 Filter bottoms and strainer systems: Departures from these standards may be acceptable for high rate filters and for proprietary bottoms. Porous plate bottoms shall not be used where iron or manganese may clog them or with waters softened by lime. The design of manifold-type collection systems shall:

- a. minimize loss of head in the manifold and laterals,
- b. ensure even distribution of washwater and even rate of filtration over the entire area of the filter,
- c. provide the ratio of the area of the final openings of the strainer systems to the area of the filter at about 0.003,
- d. provide the total cross-sectional area of the laterals at about twice the total area of the final openings,
- e. provide the cross-sectional area of the manifold at 1.5 to 2 times the total area of the laterals.
- f. lateral perforations without strainers shall be directed downward.

4.2.1.8 Surface wash or subsurface wash: Surface or subsurface wash facilities are required except for filters used exclusively for iron, radionuclides, arsenic or manganese removal, and may be accomplished by a system of fixed nozzles or a revolving-type apparatus. All devices shall be designed with

- a. provision for water pressures of at least 45 psi (310 kPa),
- b. a properly installed vacuum breaker or other approved device to prevent back siphonage if connected to the filtered or finished water system,
- c. rate of flow of 2.0 gallons per minute per square foot of filter area (4.9 m/hr) with fixed nozzles or 0.5 gallons per minute per square foot (1.2 m/hr) with revolving arms,
- d. air wash can be considered based on experimental data and operating experiences.

4.2.1.9 Air scouring: Air scouring can be considered in place of surface wash

- a. air flow for air scouring the filter must be 3–5 standard cubic feet per minute square foot of filter area (0.9 - 1.5 m³/min/m²) when the air is introduced in the underdrain; a lower air rate must be used when the air scour distribution system is placed above the underdrains,
- b. a method for avoiding excessive loss of the filter media during backwashing must be provided,
- c. air scouring must be followed by a fluidization wash sufficient to re-stratify the media,
- d. air must be free from contamination,
- e. air scour distribution systems should be placed below the media and supporting bed interface; if placed at the interface the air scour nozzles shall be designed to prevent media from clogging the nozzles or entering the air distribution system.

- f. piping for the air distribution system shall not be flexible hose which will collapse when not under air pressure and shall not be a relatively soft material which may erode at the orifice opening with the passage of air at high velocity.
- g. air delivery piping shall not pass down through the filter media nor shall there be any arrangement in the filter design which would allow short circuiting between the applied unfiltered water and the filtered water,
- h. consideration should be given to maintenance and replacement of air delivery piping,
- i. the backwash water delivery system must be capable of 15 gallons per minute per square foot of filter surface area (37 m/hr); however, when air scour is provided the backwash water rate must be variable and should not exceed 8 gallons per minute per square foot (20 m/hr) unless operating experience shows that a higher rate is necessary to remove scoured particles from filter media surfaces.
- j. the filter underdrains shall be designed to accommodate air scour piping when the piping is installed in the underdrain, and
- k. the provisions of Section 4.2.1.11 shall be followed.

4.2.1.10 Appurtenances

a. The following shall be provided for every filter:

1. influent and effluent sampling taps,
2. an indicating loss of head gauge,
3. an indicating rate-of flow meter. A modified rate controller which limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with the reviewing authority.
4. where used for surface water, provisions for filtering to waste with appropriate measures for cross connection control.
5. For systems with three or more filters, on-line turbidimeters shall be installed on the effluent line from each filter. All turbidimeters shall consistently determine and indicate the turbidity of the water in NTUs. Each turbidimeter shall report to a recorder that is designed and operated to allow the operator to accurately determine the turbidity at least once every 15 minutes. Turbidimeters on individual filters should be designed to accurately measure low-range turbidities and have an alarm that will sound when the effluent level exceeds 0.3 NTU.

b. It is recommended the following be provided for every filter:

1. wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing,
2. a 1 to 1.5 inch pressure hose and storage rack at the operating floor for washing filter walls,
3. particle monitoring equipment as a means to enhance overall treatment operations where used for surface water,
4. a flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

4.2.1.11 Backwash: Provisions shall be made for washing filters as follows:

- a. a minimum rate of 15 gallons per minute per square foot (37 m/hr), consistent with water temperatures and specific gravity of the filter media. A rate of 20 gallons per minute per square foot (50 m/hr) or a rate necessary to provide for a 50 percent expansion of the filter bed is recommended. A reduced rate of 10 gallons per minute per square foot (24 m/hr) may be acceptable for full depth anthracite or granular activated carbon filters,
- b. filtered water provided at the required rate by washwater tanks, a washwater pump, from the high service main, or a combination of these,
- c. washwater pumps in duplicate unless an alternate means of obtaining washwater is available,
- d. not less than 15 minutes wash of one filter at the design rate of wash,
- e. a washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with the washwater valves on the individual filters open wide,
- f. a rate-of-flow indicator, preferably with a totalizer, on the main washwater line, located so that it can be easily read by the operator during the washing process,
- g. design to prevent rapid changes in backwash water flow.
- h. backwash shall be operator initiated. Automated systems shall be operator adjustable.

4.2.1.12 Miscellaneous

Roof drains shall not discharge into the filters or basins and conduits preceding the filters.

4.2.2 Rapid rate pressure filters: The normal use of these filters is for iron and manganese removal. Pressure filters shall not be used in the filtration of surface or other polluted waters or following lime-soda softening.

4.2.2.1 General: Minimum criteria relative to rate of filtration, structural details and hydraulics, filter media, etc., provided for rapid rate gravity filters also apply to pressure filters where appropriate.

4.2.2.2 Rate of filtration: The rate shall not exceed three gallons per minute per square foot of filter area (7.2 m/hr) except where inplant testing as approved by the reviewing authority has demonstrated satisfactory results at higher rates.

4.2.2.3 Details of design: The filters shall be designed to provide for

- a. loss of head gauges on the inlet and outlet pipes of each battery of filters,
- b. an easily readable meter or flow indicator on each battery of filters. A flow indicator is recommended for each filtering unit,
- c. filtration and backwashing of each filter individually with an arrangement of piping as simple as possible to accomplish these purposes,
- d. minimum side wall shell height of five feet. A corresponding reduction in side wall height is acceptable where proprietary bottoms permit reduction of the gravel depth,
- e. the top of the washwater collectors to be at least 18 inches above the surface of the media,
- f. the underdrain system to efficiently collect the filtered water and to uniformly distribute the backwash water at a rate not less than 15 gallons per minute per square foot of filter area (37 m/hr),
- g. backwash flow indicators and controls that are easily readable while operating the control valves,
- h. an air release valve on the highest point of each filter,
- i. an accessible manhole of adequate size to facilitate inspection and repairs for filters 36 inches or more in diameter. Sufficient handholds shall be provided for filters less than 36 inches in diameter. Manholes should be at least 24 inches in diameter where feasible,
- j. means to observe the wastewater during backwashing,
- k. construction to prevent cross-connection.

4.2.3 Diatomaceous earth filtration: The use of these filters may be considered for application to surface waters with low turbidity and low bacterial contamination.

4.2.3.1 Conditions of use: Diatomaceous earth filters are expressly excluded from consideration for the following conditions:

- a. bacteria removal,
- b. color removal,
- c. turbidity removal where either the gross quantity of turbidity is high or the turbidity exhibits poor filterability characteristics,
- d. filtration of waters with high algae counts.

4.2.3.2 Pilot plant study: Installation of a diatomaceous earth filtration system shall be preceded by a pilot plant study on the water to be treated.

- a. Conditions of the study such as duration, filter rates, head loss accumulation, slurry feed rates, turbidity removal, bacteria removal, etc., must be approved by the reviewing authority prior to the study.
- b. Satisfactory pilot plant results must be obtained prior to preparation of final construction plans and specifications.
- c. The pilot plant study must demonstrate the ability of the system to meet applicable drinking water standards at all times.

4.2.3.3 Types of filters: Pressure or vacuum diatomaceous earth filtration units will be considered for approval. However, the vacuum type is preferred for its ability to accommodate a design which permits observation of the filter surfaces to determine proper cleaning, damage to a filter element, and adequate coating over the entire filter area.

4.2.3.4 Treated water storage: Treated water storage capacity in excess of normal requirements shall be provided to:

- a. allow operation of the filters at a uniform rate during all conditions of system demand at or below the approved filtration rate, and,
- b. guarantee continuity of service during adverse raw water conditions without by-passing the system.

4.2.3.5 Number of units

See Section 4.2.1.3

4.2.3.6 Precoat

- a. **Application** – A uniform precoat shall be applied hydraulically to each septum by introducing a slurry to the tank influent line and employing a filter-to-waste or recirculation system.
- b. **Quantity** – Diatomaceous earth in the amount of 0.2 pounds per square foot of filter area (0.98 kg/m²) or an amount sufficient to apply a 1/8 inch coating should be used with recirculation.

4.2.3.7 Body feed: A body feed system to apply additional amounts of diatomaceous earth slurry during the filter run is required to avoid short filter runs or excessive head losses.

- a. **Quantity** – Rate of body feed is dependent on raw water quality and characteristics and must be determined in the pilot plant study.
- b. Operation and maintenance can be simplified by providing accessibility to the feed system and slurry lines.
- c. Continuous mixing of the body feed slurry is required.

4.2.3.8 Filtration

- a. **Rate of filtration** – The recommended nominal rate is 1.0 gallon per minute per square foot of filter area (2.4 m/hr) with a recommended maximum of

1.5 gallons per minute per square foot (3.7 m/hr). The filtration rate shall be controlled by a positive means.

- b. Head loss** – The head loss shall not exceed 30 psi (210 kPa) for pressure diatomaceous earth filters, or a vacuum of 15 inches of mercury (-51 kPa) for a vacuum system.
- c. Recirculation** – A recirculation or holding pump shall be employed to maintain differential pressure across the filter when the unit is not in operation in order to prevent the filter cake from dropping off the filter elements. A minimum recirculation rate of 0.1 gallon per minute per square foot of filter area (0.24 m/hr) shall be provided.
- d. Septum or filter element** – The filter elements shall be structurally capable of withstanding maximum pressure and velocity variations during filtration and backwash cycles, and shall be spaced such that no less than one inch is provided between elements or between any element and a wall.
- e. Inlet design** – The filter influent shall be designed to prevent scour of the diatomaceous earth from the filter element.

4.2.3.9 Backwash: A satisfactory method to thoroughly remove and dispose of spent filter cake shall be provided.

4.2.3.10 Appurtenances

- a.** The following shall be provided for every filter:
 - 1. sampling taps for raw and filtered water,
 - 2. loss of head or differential pressure gauge,
 - 3. rate-of-flow indicator, preferably with totalizer,
 - 4. a throttling valve used to reduce rates below normal during adverse raw water conditions,
 - 5. evaluation of the need for body feed, recirculation, and any other pumps, in accordance with Section 6.3.
 - 6. provisions for filtering to waste with appropriate measures for backflow prevention (see Part 9).
- b. It is recommended the following be provided:**
 - 1. A 1 to 1.5 inch pressure hose and storage rack at the operating floor for washing the filter.
 - 2. Access to particle counting equipment as a means to enhance overall treatment operations.
 - 3. A throttling valve used to reduce rates below normal during adverse raw water conditions.
 - 4. Evaluation of the need for body feed, recirculation, and any other pumps, in accordance with Section 6.3.

5. A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.
6. A continuous monitoring turbidimeter with recorder on each filter effluent for plants treating surface water.

4.2.4 Slow sand filters: The use of these filters shall require prior engineering studies to demonstrate the adequacy and suitability of this method of filtration for the specific raw water supply.

4.2.4.1 Quality of raw water: Slow rate gravity filtration shall be limited to waters having maximum turbidities of 10 units and maximum color of 15 units; such turbidity must not be attributable to colloidal clay. Microscopic examination of the raw water must be made to determine the nature and extent of algae growths and their potential adverse impact on filter operations.

4.2.4.2 Number: At least two units shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service.

4.2.4.3 Structural details and hydraulics: Slow rate gravity filters shall be so designed as to provide:

- a. a cover,
- b. headroom to permit normal movement by operating personnel for scraping and sand removal operations,
- c. adequate access hatches and access ports for handling of sand and for ventilation,
- d. an overflow at the maximum filter water level, and
- e. protection from freezing.

4.2.4.4 Rates of filtration: The permissible rates of filtration shall be determined by the quality of the raw water and shall be on the basis of experimental data derived from the water to be treated. The nominal rate may be 45 to 150 gallons per day per square foot of sand area (1.8 - 6.1 m/day), with somewhat higher rates acceptable when demonstrated to the satisfaction of the approving authority.

4.2.4.5 Underdrains: Each filter unit shall be equipped with a main drain and an adequate number of lateral underdrains to collect the filtered water. The underdrains shall be placed as close to the floor as possible and spaced so that the maximum velocity of the water flow in the underdrain will not exceed 0.75 feet per second. The maximum spacing of laterals shall not exceed 3 feet if pipe laterals are used.

4.2.4.6 Filter material

- a. Filter sand shall be placed on graded gravel layers for a minimum depth of 30 inches.
- b. The effective size shall be between 0.15 mm and 0.30 mm. Larger sizes may be considered by the reviewing authority; a pilot study may be required.
- c. The uniformity coefficient shall not exceed 2.5.
- d. The sand shall be cleaned and washed free from foreign matter.
- e. The sand shall be rebedded when scraping has reduced the bed depth to no less than 19 inches. Where sand is to be reused in order to provide biological seeding and shortening of the ripening process, rebedding shall utilize a “throw over” technique whereby new sand is placed on the support gravel and existing sand is replaced on top of the new sand.

4.2.4.7 Filter gravel: The supporting gravel should be similar to the size and depth distribution provided for rapid rate gravity filters. See 4.2.1.6.f.2.

4.2.4.8 Depth of water on filter beds: Design shall provide a depth of at least three to six feet of water over the sand. Influent water shall not scour the sand surface.

4.2.4.9 Control appurtenances: Each filter shall be equipped with:

- a. influent and effluent sampling taps.
- b. an indicating loss of head gauge or other means to measure head loss.
- c. an indicating rate-of-flow meter. A modified rate controller that limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with the reviewing authority.
- d. provisions for filtering to waste with appropriate measures for cross connection control.
- e. an orifice, Venturi meter, or other suitable means of discharge measurement installed on each filter to control the rate of filtration,
- f. an effluent pipe designed to maintain the water level above the top of the filter sand.

4.2.4.10 Ripening: Slow sand filters shall be operated to waste after scraping or rebedding during a ripening period until the filter effluent turbidity falls to consistently below the regulated drinking water standard established for the system.

4.2.5 Direct filtration: Direct filtration, as used herein, refers to the filtration of a surface water following chemical coagulation and possibly flocculation but without prior settling. The nature of the treatment process will depend upon the raw water quality. A full scale direct filtration plant shall not be constructed without prior pilot studies which are acceptable to the reviewing authority. In-plant demonstration studies may be

appropriate where conventional treatment plants are converted to direct filtration. Where direct filtration is proposed, an engineering report shall be submitted prior to conducting pilot plant or in-plant demonstration studies.

4.2.5.1 Engineering report: In addition to the items considered in Section 1.1, "Engineering Report", the report should include a historical summary of meteorological conditions and of raw water quality with special reference to fluctuations in quality, and possible sources of contamination. The following raw water parameters should be evaluated in the report:

- a. color,
- b. turbidity,
- c. bacterial concentration,
- d. microscopic biological organisms,
- e. temperature,
- f. total solids,
- g. general inorganic chemical characteristics,
- h. additional parameters as required by the reviewing authority.

The report should also include a description of methods and work to be done during a pilot plant study or, where appropriate, an in-plant demonstration study.

4.2.5.2 Pilot plant studies: After approval of the engineering report, a pilot study or in-plant demonstration study shall be conducted. The study must be conducted over a sufficient time to treat all expected raw water conditions throughout the year. The study shall emphasize but not be limited to, the following items:

- a. chemical mixing conditions including shear gradients and detention periods,
- b. chemical feed rates,
- c. use of various coagulants and coagulant aids,
- d. flocculation conditions,
- e. filtration rates,
- f. filter gradation, types of media and depth of media,
- g. filter breakthrough conditions, and
- h. adverse impact of recycling backwash water due to solids, algae, trihalomethane formation and similar problems.
- i. length of filter runs,
- j. length of backwash cycles,
- k. quantities and make-up of the wastewater.

Prior to the initiation of design plans and specifications, a final report including the engineer's design recommendations shall be submitted to the reviewing

authority. The pilot plant filter must be of a similar type and operated in the same manner as proposed for full scale operation. The pilot study must demonstrate the minimum contact time necessary for optimum filtration for each coagulant proposed.

4.2.5.3 Pretreatment – Coagulation and flocculation: The final coagulation and flocculation basin design should be based on the pilot plant or in-plant demonstration studies augmented with applicable portions of Section 4.1.2, "Coagulation" and Section 4.1.3, "Flocculation."

4.2.5.4 Filtration: Filters shall be rapid rate gravity filters with dual or mixed media. The final filter design shall be based on the pilot plant or in-plant demonstration studies and all portions of Section 4.2.1, "Rapid Rate Gravity Filters." Pressure filters or single media sand filters shall not be used.

4.2.5.5 Appurtenances:

a. The following shall be provided for every filter:

1. influent and effluent sampling taps,
2. an indicating loss of head gauge,
3. an indicating rate-of flow meter. A modified rate controller which limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with the reviewing authority.
4. where used for surface water, provisions for filtering to waste with appropriate measures for cross connection control.
5. For systems with three or more filters, on-line turbidimeters shall be installed on the effluent line from each filter. All turbidimeters shall consistently determine and indicate the turbidity of the water in NTUs. Each turbidimeter shall report to a recorder that is designed and operated to allow the operator to accurately determine the turbidity at least once every 15 minutes. Turbidimeters on individual filters should be designed to accurately measure low-range turbidities and have an alarm that will sound when the effluent level exceeds 0.3 NTU.

b. It is recommended the following be provided for every filter:

1. wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing,
2. a 1 to 1.5 inch pressure hose and storage rack at the operating floor for washing filter walls,
3. particle monitoring equipment as a means to enhance overall treatment operations where used for surface water,

4. a flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

4.2.5.6 Siting requirements: The plant design and land ownership surrounding the plant shall allow for modifications of the plant.

4.2.6 Deep bed rapid rate gravity filters

4.2.6.1 Deep bed rapid rate gravity filters, as used herein, generally refers to rapid rate gravity filters with filter material depths equal to or greater than 48 inches. Filter media sizes are typically larger than those listed in Section 4.2.1.6 (d).

4.2.6.2: Deep bed rapid rate filters may be considered based on pilot studies pre approved by the reviewing authority.

4.2.6.3: The final filter design shall be based on the pilot plant studies and shall comply with all applicable portions of Section

4.2.7 Biologically active filters

4.2.7.1: Biologically active filtration, as used herein, refers to the filtration of a surface water (or a ground water with iron, manganese or significant natural organic material) which includes the establishment and maintenance of biological activity within the filtration media. Objectives of biologically active filtration may include control of disinfection byproduct precursors, increased disinfectant stability, reduction of substrates for microbial regrowth, breakdown of small quantities of synthetic organic chemicals, reduction of ammonia-nitrogen, and oxidation of iron and manganese. Biological activity can have an adverse impact on turbidity, particle and microbial pathogen removal, disinfection practices; head loss development; filter run times and distribution system corrosion. Design and operation should ensure that aerobic conditions are maintained at all times. Biologically active filtration often includes the use of ozone as a pre-oxidant/disinfectant which breaks down natural organic materials into biodegradable organic matter and granular activated carbon filter media which may promote denser biofilms.

Biologically active filters may be considered based on pilot studies pre-approved by the reviewing authority. The study objectives must be clearly defined and must ensure the microbial quality of the filtered water under all anticipated conditions of operation. The pilot study shall be of sufficient duration to ensure establishment of full biological activity; often greater than three months is required. Also, the pilot study shall establish empty bed contact time, biomass loading, and/or other parameters necessary for successful operation as required by the reviewing authority.

4.2.7.2: The final filter design shall be based on the pilot plant studies and shall comply with all applicable portions of [Section 4.2.1](#).

4.3 DISINFECTION: Chlorine is historically the preferred disinfecting agent. Disinfection may be accomplished with gas and liquid chlorine, calcium or sodium hypochlorites, chlorine dioxide, ozone, or ultraviolet light. Other disinfecting agents will be considered, providing reliable application equipment is available and testing procedures for a residual are recognized in "Standard Methods for the Examination of Water and Wastewater," latest edition or an

equivalent means of measuring effectiveness exists. Disinfection is required for all surface water supplies, groundwater under the direct influence of surface water, and for any groundwater supply of questionable sanitary quality or where other treatment is provided. Disinfection with chloramines is not recommended for primary disinfection. The required amount of primary disinfection needed shall be specified by the reviewing authority. Continuous disinfection is recommended for all water supplies. Consideration must be given to the formation of disinfection byproducts (DBP) when selecting the disinfectant.

4.3.1 Chlorination equipment

- 4.3.1.1 **Type:** Solution-feed gas chlorinators or hypochlorite feeders of the positive displacement type must be provided. (see Part 5).
- 4.3.1.2 **Capacity:** The chlorinator capacity shall be such that a free chlorine residual of at least 2 mg/L can be maintained in the water once all demands are met after contact time of at least 30 minutes when maximum flow rate coincides with anticipated maximum chlorine demand. The equipment shall be of such design that it will operate accurately over the desired feeding range.
- 4.3.1.3 **Standby equipment:** Where chlorination is required for protection of the supply, standby equipment of sufficient capacity shall be available to replace the largest unit. Spare parts shall be made available to replace parts subject to wear and breakage. If there is a large difference in feed rates between routine and emergency dosages, a gas metering tube should be provided for each dose range to ensure accurate control of the chlorine feed.
- 4.3.1.4 **Automatic switch-over:** Automatic switch-over of chlorine cylinders should be provided, where necessary, to assure continuous disinfection.
- 4.3.1.5 **Automatic proportioning:** Automatic proportioning chlorinators will be required where the rate of flow or chlorine demand is not reasonably constant.
- 4.3.1.6 **Eductor:** Each eductor must be selected for the point of application with particular attention given to the quantity of chlorine to be added, the maximum injector waterflow, the total discharge back pressure, the injector operating pressure, and the size of the chlorine solution line. Gauges for measuring water pressure and vacuum at the inlet and outlet of each eductor should be provided.
- 4.3.1.7 **Injector/diffuser:** The chlorine solution injector/diffuser must be compatible with the point of application to provide a rapid and thorough mix with all the water being treated. The center of a pipeline is the preferred application point.

4.3.2 Contact time and point of application

- a. Due consideration shall be given to the contact time of the disinfectant in water with relation to pH, ammonia, taste-producing substances, temperature, bacterial quality, disinfection byproduct formation potential and other pertinent factors. The disinfectant should be applied at a point which will provide adequate contact time. All basins used for disinfection must be designed to minimize short circuiting. Additional baffling can be added to new or existing basins to minimize short circuiting and increase contact time.

- b. At plants treating surface water, provisions shall be made for applying the disinfectant to the raw water, settled water, filtered water, and water entering the distribution system.
- c. As a minimum, at plants treating groundwater, provisions shall be made for applying the disinfectant to the detention basin inlet and water entering the distribution system.
- d. The amount of contact time provided will depend on the type of disinfectant used along with the parameters mentioned in 4.3.2.a. As a minimum, for surface waters and groundwaters under the direct influence of surface water, the system must be designed to meet the CT standards set by the reviewing authority. If primary disinfection is accomplished using ozone or some other chemical that does not provide a residual disinfectant, then chlorine must be added to provide a residual disinfectant as mentioned in 4.3.3. Disinfection for groundwaters shall be as determined by the reviewing authority.

4.3.3 Residual chlorine

- a. Minimum free chlorine residual in a water distribution system should be 0.2 mg/L. Minimum chloramine residuals, where chloramination is practiced, should be 1.0 mg/L at distant points in the distribution system.
- b. Higher residuals may be required depending on pH, temperature and other characteristics of the water.

4.3.4 Testing equipment

- a. Chlorine residual test equipment recognized in the latest edition of Standard Methods for the Examination of Water and Wastewater shall be provided and should be capable of measuring residuals to the nearest 0.1 milligrams per liter. It is recommended that all systems, as a minimum, use an instrument using the DPD colorimetric method with a digital readout and a self contained light source.
- b. Automatic chlorine residual recorders should be provided where the chlorine demand varies appreciably over a short period of time.
- c. All treatment plants having a capacity of 0.5 million gallons per day or greater should be equipped with recording chlorine analyzers monitoring water entering the distribution system. (see Section 2.9).
- d. All surface water treatment plants that serve a population greater than 3300 must have equipment to measure chlorine residuals continuously entering the distribution system.
- e. Systems that rely on chlorination for inactivation of bacteria or other microorganisms present in the source water shall have continuous chlorine residual analyzers and other equipment that automatically shut down the facility when chlorine residuals are not met unless otherwise approved by the reviewing authority.

4.3.5 Chlorinator piping

4.3.5.1 Cross-connection protection: The chlorinator water supply piping shall be designed to prevent contamination of the treated water supply by sources of questionable quality. At all facilities treating surface water, pre- and post-chlorination systems must be independent to prevent possible siphoning of partially treated water into the clear well. The water supply to each eductor shall have a separate shut-off valve. No master shut-off valve will be allowed.

4.3.5.2 Pipe material: The pipes carrying elemental liquid or dry gaseous chlorine under pressure must be Schedule 80 seamless steel tubing or other materials recommended by the Chlorine Institute (never use PVC). Rubber, PVC, polyethylene, or other materials recommended by the Chlorine Institute must be used for chlorine solution piping and fittings. Nylon products are not acceptable for any part of the chlorine solution piping system.

4.3.6 Housing: Adequate housing must be provided for the chlorination equipment and for storing the chlorine.

4.3.7 Ozone

4.3.7.1 Design considerations: Ozonation systems are generally used for the purpose of disinfection, oxidation and microflocculation. When applied, all of these reactions may occur but typically only one is the primary purpose for its use. The other reactions would become secondary benefits of the installation. Effective disinfection occurs as demonstrated by the fact that the "CT" values for ozone, for inactivation of viruses and Giardia cysts, are considerably lower than the "CT" values for other disinfectants. In addition, recent research indicates that ozone can be an effective disinfectant for the inactivation of cryptosporidium. Microflocculation and enhanced filterability has been demonstrated for many water supplies but has not occurred in all waters. Oxidation of organic compounds such as color, taste and odor, and detergents and inorganic compounds such as iron, manganese, heavy metals and hydrogen sulfide has been documented. The effectiveness of oxidation has been varied, depending on pH and alkalinity of the water. These parameters affect the formation of highly reactive hydroxyl radicals, or, conversely the scavenging of this oxidant.

High levels of hydroxyl radicals cause lower levels of residual ozone. Depending on the desired oxidation reaction, it may be necessary to maximize ozone residual or maximize hydroxyl radical formation. For disinfection, residual ozone is necessary for development of "CT". As a minimum, bench scale studies shall be conducted to determine minimum and maximum ozone dosages for disinfection "CT" compliance and oxidation reactions. More involved pilot studies shall be conducted when necessary to document benefits and DBP precursor removal effectiveness. Consideration shall be given to multiple points of ozone addition. Pilot studies shall be conducted for all surface waters. Extreme care must be taken during bench and pilot scale studies to ensure accurate results. Particularly sensitive measurements include gas flow rate, water flow rate, and ozone concentration.

Following the use of ozone, the application of a disinfectant which maintains a measurable residual will be required in order to ensure a bacteriologically safe

water is carried throughout the distribution system. Furthermore, because of the more sophisticated nature of the ozone process a higher degree of operator maintenance skills and training is required. The ability to obtain qualified operators must be evaluated in selection of the treatment process. The necessary operator training shall be provided prior to plant startup. The production of ozone is an energy intensive process: substantial economies in electrical usage, reduction in equipment size, and waste heat removal requirements can be obtained by using oxygen enriched air or 100% oxygen as feed, and by operating at increased electrical frequency.

Use of ozone may result in increases in biologically available organics content of the treated water. Consideration of biologically active filtration may be required to stabilize some treated waters. Ozone use may also lead to increased chlorinated byproduct levels if the water is not stabilized and free chlorine is used for distribution protection.

4.3.7.2 Feed Gas Preparation

a. General: Feed gas can be air, oxygen enriched air, or high purity oxygen. Sources of high purity oxygen include purchased liquid oxygen; on site generation using cryogenic air separation; or temperature, pressure or vacuum swing (adsorptive separation) technology. For high purity oxygen-feed systems, dryers typically are not required. Air handling equipment on conventional low pressure air feed systems shall consist of an air compressor, water/air separator, refrigerant dryer, heat reactivated desiccant dryer, and particulate filters. Some "package" ozonation systems for small plants may work effectively operating at high pressure without the refrigerant dryer and with a "heat-less" desiccant dryer. In all cases the design engineer must ensure that the maximum dew point of -76oF (-60oC) will not be exceeded at any time.

b. Air Compression

1. Air compressors shall be of the liquid-ring or rotary lobe, oil-less, positive displacement type for smaller systems or dry rotary screw compressors for larger systems.
2. The air compressors shall have the capacity to simultaneously provide for maximum ozone demand, provide the air flow required for purging the desiccant dryers (where required) and allow for standby capacity.
3. Air feed for the compressor shall be drawn from a point protected from rain, condensation, mist, fog and contaminated air sources to minimize moisture and hydrocarbon content of the air supply.
4. A compressed air after-cooler and/or entrainment separator with automatic drain shall be provided prior to the dryers to reduce the water vapor.
5. A back-up air compressor must be provided so that ozone generation is not interrupted in the event of a break-down.

c. Air Drying

1. Dry, dust-free and oil-free feed gas must be provided to the ozone generator. Dry gas is essential to prevent formation of nitric acid, to increase the efficiency of ozone generation and to prevent damage to the generator dielectrics. Sufficient drying to a maximum dew point of -76oF (-60oC) must be provided at the end of the drying cycle.
2. Drying for high pressure systems may be accomplished using heatless desiccant dryers only. For low pressure systems, a refrigeration air dryer in series with heat-activated desiccant dryers shall be used.
3. A refrigeration dryer capable of reducing inlet air temperature to 40oF (4oC). shall be provided for low pressure air preparation systems. The dryer can be of the compressed refrigerant type or chilled water type.
4. For heat-activated desiccant dryers, the unit shall contain two desiccant filled towers complete with pressure relief valves, two four-way valves and a heater. In addition, external type dryers shall have a cooler unit and blowers. The size of the unit shall be such that the specified dew point will be achieved during a minimum adsorption cycle time of 16 hours while operating at the maximum expected moisture loading conditions.
5. Multiple air dryers shall be provided so that the ozone generation is not interrupted in the event of dryer breakdown.
6. Each dryer shall be capable of venting "dry" gas to the atmosphere, prior to the ozone generator, to allow start-up when other dryers are "on-line".

d. Air Filters

1. Air filters shall be provided on the suction side of the air compressors, between the air compressors and the dryers and between the dryers and the ozone generators.
2. The filter before the desiccant dryers shall be of the coalescing type and be capable of removing aerosol and particulates larger than 0.3 microns in diameter. The filter after the desiccant dryer shall be of the particulate type and be capable of removing all particulates greater than 0.1 microns in diameter, or smaller if specified by the generator manufacturer.

- e. Preparation Piping:** Piping in the air preparation system can be common grade steel, seamless copper, stainless steel or galvanized steel. The piping must be designed to withstand the maximum pressures in the air preparation system.

4.3.7.3 Ozone Generator

a. Capacity

1. The production rating of the ozone generators shall be stated in pounds per day and kWhr per pound at a maximum cooling water temperature and maximum ozone concentration.
 2. The design shall ensure that the minimum concentration of ozone in the generator exit gas will not be less than 1 percent (by weight).
 3. Generators shall be sized to have sufficient reserve capacity so that the system does not operate at peak capacity for extended periods of time. This can result in premature breakdown of the dielectrics.
 4. The production rate of ozone generators will decrease as the temperature of the coolant increases. If there is to be a variation in the supply temperature of the coolant throughout the year, then pertinent data shall be used to determine production changes due to the temperature change of the supplied coolant. The design shall ensure that the generators can produce the required ozone at maximum coolant temperature.
 5. Appropriate ozone generator backup equipment must be provided.
- b. Electrical:** The generators can be low, medium or high frequency type. Specifications shall require that the transformers, electronic circuitry and other electrical hardware be proven, high quality components designed for ozone service.
- c. Cooling:** Adequate cooling shall be provided. The required water flow to an ozone generator varies with the ozone production. Normally unit design provides a maximum cooling water temperature rise of 5oF (2.8oC). The cooling water must be properly treated to minimize corrosion, scaling and microbiological fouling of the water side of the tubes. A closed loop cooling water system is often used to insure proper water conditions are maintained. Where cooling water is treated cross connection control shall be provided to prevent contamination of the potable water supply in accordance with [Section 8.10.2](#).
- d. Materials:** To prevent corrosion, the ozone generator shell and tubes shall be constructed of Type 316L stainless steel.
- 4.3.7.4 Ozone Contactors:** The selection or design of the contactor and method of ozone application depends on the purpose for which the ozone is being used.
- a. Bubble Diffusers**
1. Where disinfection is the primary application a minimum of two contact chambers each equipped with baffles to prevent short circuiting and induce countercurrent flow shall be provided. Ozone shall be applied using porous-tube or dome diffusers.
 2. The minimum contact time shall be 10 minutes. A shorter contact time may be approved by the reviewing authority if justified by appropriate design and "CT" considerations.

3. For ozone applications in which precipitates are formed, such as with iron and manganese removal, porous diffusers should be used with caution.
 4. Where taste and odor control is of concern, multiple application points and contactors shall be considered.
 5. Contactors should be separate closed vessels that have no common walls with adjacent rooms. The contactor must be kept under negative pressure and sufficient ozone monitors shall be provided to protect worker safety. Placement of the contactor where the entire roof is exposed to the open atmosphere is recommended.
 6. Large contact vessels should be made of reinforced concrete. All reinforcement bars shall be covered with a minimum of 1.5 inches of concrete. Smaller contact vessels can be made of stainless steel, fiberglass or other material which will be stable in the presence of residual ozone and ozone in the gas phase above the water level.
 7. Where necessary a system shall be provided between the contactor and the off-gas destruct unit to remove froth from the air and return the other to the contactor or other location acceptable to the reviewing authority. If foaming is expected to be excessive, then a potable water spray system shall be placed in the contactor head space.
 8. All openings into the contactor for pipe connections, hatchways, etc. shall be properly sealed using welds or ozone resistant gaskets such as Teflon or Hypalon.
 9. Multiple sampling ports shall be provided to enable sampling of each compartment's effluent water and to confirm "CT" calculations.
 10. A pressure/vacuum relief valve shall be provided in the contactor and piped to a location where there will be no damage to the destruction unit.
 11. The diffusion system should work on a countercurrent basis such that the ozone is fed at the bottom of the vessel and water is fed at the top of the vessel.
 12. The depth of water in bubble diffuser contactors should be a minimum of 18 feet. The contactor should also have a minimum of 3 feet of freeboard to allow for foaming.
 13. All contactors shall have provisions for cleaning, maintenance and drainage of the contactor. Each contactor compartment shall also be equipped with an access hatchway.
 14. Aeration diffusers shall be fully serviceable by either cleaning or replacement.
- b. Other contactors:** Other contactors, such as the venturi or aspirating turbine mixer contactor, may be approved by the reviewing authority

provided adequate ozone transfer is achieved and the required contact times and residuals can be met and verified.

4.3.7.5 Ozone Destruction Unit

- a. A system for treating the final off-gas from each contactor must be provided in order to meet safety and air quality standards. Acceptable systems include thermal destruction and thermal/catalytic destruction units.
- b. In order to reduce the risk of fires, the use of units that operate at lower temperatures is encouraged, especially where high purity oxygen is the feed gas.
- c. The maximum allowable ozone concentration in the discharge is 0.1 ppm (by volume).
- d. At least two units shall be provided which are each capable of handling the entire gas flow.
- e. Exhaust blowers shall be provided in order to draw off-gas from the contactor into the destruct unit.
- f. Catalysts must be protected from froth, moisture and other impurities which may harm the catalyst.
- g. The catalyst and heating elements shall be located where they can easily be reached for maintenance.

4.3.7.6 Piping Materials: Only low carbon 304L and 316L stainless steels shall be used for ozone service with 316L the preferred.

4.3.7.7 Joints and Connections

- a. Connections on piping used for ozone service are to be welded where possible.
- b. Connections with meters, valves or other equipment are to be made with flanged joints with ozone resistant gaskets, such as Teflon or Hypalon. Screwed fittings shall not be used because of their tendency to leak.
- c. A positive closing plug or butterfly valve plus a leak-proof check valve shall be provided in the piping between the generator and the contactor to prevent moisture reaching the generator.

4.3.7.8 Instrumentation

- a. Pressure gauges shall be provided at the discharge from the air compressor, at the inlet to the refrigeration dryers, at the inlet and outlet of the desiccant dryers, at the inlet to the ozone generators and contactors and at the inlet to the ozone destruction unit.
- b. Electric power meters should be provided for measuring the electric power supplied to the ozone generators. Each generator shall have a trip which shuts down the generator when the wattage exceeds a certain preset level.

- c. Dew point monitors shall be provided for measuring the moisture of the feed gas from the desiccant dryers. Because it is critical to maintain the specified dew point, it is recommended that continuous recording charts be used for dew point monitoring which will allow for proper adjustment of the dryer cycle. Where there is potential for moisture entering the ozone generator from downstream of the unit or where moisture accumulation can occur in the generator during shutdown, post-generator dew point monitors shall be used.
- d. Air flow meters shall be provided for measuring air flow from the desiccant dryers to each of other ozone generators, air flow to each contactor and purge air flow to the desiccant dryers.
- e. Temperature gauges shall be provided for the inlet and outlet of the ozone cooling water and the inlet and outlet of the ozone generator feed gas, and, if necessary, for the inlet and outlet of the ozone power supply cooling water.
- f. Water flow meters shall be installed to monitor the flow of cooling water to the ozone generators and, if necessary, to the ozone power supply.
- g. Ozone monitors shall be installed to measure zone concentration in both the feed-gas and off-gas from the contactor and in the off-gas from the destruct unit. For disinfection systems, monitors shall also be provided for monitoring ozone residuals in the water. The number and location of ozone residual monitors shall be such that the amount of time that the water is in contact with the ozone residual can be determined.
- h. A minimum of one ambient ozone monitor shall be installed in the vicinity of the contactor and a minimum of one shall be installed in the vicinity of the generator. Ozone monitors shall also be installed in any areas where ozone gas may accumulate.

4.3.7.9 Alarms: The following alarm/shutdown systems should be considered at each installation:

- a. Dew point shutdown/alarm – This system should shut down the generator in the event the system dew point exceeds -76oF (-60oC).
- b. Ozone generator cooling water flow shutdown/alarm – This system should shut down the generator in the event that cooling water flows decrease to the point that generator damage could occur.
- c. Ozone power supply cooling water flow shutdown/alarm – This system should shut down the power supply in the event that cooling water flow decreases to the point that damage could occur to the power supply.
- d. Ozone generator cooling water temperature shutdown/alarm – This system should shutdown the generator if either the inlet or outlet cooling water exceeds a certain preset temperature.

- e. Ozone power supply cooling water temperature shutdown/alarm – This system should shutdown the power supply if either the inlet or outlet cooling water exceeds a certain preset temperature.
- f. Ozone generator inlet feed-gas temperature shutdown/alarm – This system should shutdown the generator if the feed-gas temperature is above a preset value.
- g. Ambient ozone concentration shutdown/alarm – The alarm should sound when the ozone level in the ambient air exceeds 0.1 ppm or a lower value chosen by the water supplier. Ozone generator shutdown should occur when ambient ozone levels exceed 0.3 ppm (or a lower value) in either the vicinity of the ozone generator or the contactor.
- h. Ozone destruct temperature alarm – The alarm should sound when temperature exceeds a preset value.

4.3.7.10 Safety

- a. The maximum allowable ozone concentration in the air to which workers may be exposed must not exceed 0.1 ppm (by volume).
- b. Noise levels resulting from the operating equipment of the ozonation system shall be controlled to within acceptable limits by special room construction and equipment isolation.
- c. High voltage and high frequency electrical equipment must meet current electrical and fire codes.
- d. Emergency exhaust fans must be provided in the rooms containing the ozone generators to remove ozone gas if leakage occurs.
- e. A portable purge air blower that will remove residual ozone in the contactor prior to entry for repair or maintenance should be provided.
- f. A sign shall be posted indicating “No smoking, oxygen in use” at all entrances to the treatment plant. In addition, no flammable or combustible materials shall be stored within the oxygen generator areas.

4.3.7.11 Construction Considerations

- a. Prior to connecting the piping from the desiccant dryers to the ozone generators the air compressors should be used to blow the dust out of the desiccant.
- b. The contactor should be tested for leakage after sealing the exterior. This can be done by pressurizing the contactor and checking for pressure losses.
- c. Connections on the ozone service line should be tested for leakage using the soap-test method.

4.3.8 Chlorine dioxide: Chlorine dioxide may be considered as a primary and residual disinfectant, a pre-oxidant to control tastes and odors, to oxidize iron and manganese, and to control hydrogen sulfide and phenolic compounds. It has been shown to be a

strong disinfectant which does not form THMs or HAAs. When choosing chlorine dioxide, consideration must be given to formation of the regulated byproducts, chlorite and chlorate.

4.3.8.1 Chlorine dioxide generators: Chlorine dioxide generation equipment shall be factory assembled pre-engineered units with a minimum efficiency of 95 percent. The excess free chlorine shall not exceed three percent of the theoretical stoichiometric concentration required.

4.3.8.2 Feed and storage facilities: Chlorine gas and sodium chlorite feed and storage facilities shall comply with sections 5.4.1 and 5.4.3, respectively. Sodium hypochlorite feed and storage facilities shall comply with section 5.4.4.

4.3.8.3 Other design requirements

- a. The design shall comply with all applicable portions of sections 4.3.1, 4.3.2, 4.3.4, and 4.3.5.
- b. The minimum residual disinfectant level shall be established by the reviewing authority.

4.3.8.4 Public notification: Notification of a change in disinfection practices and the schedule for the changes shall be made known to the public; particularly to hospitals, kidney dialysis facilities and fish breeders, as chlorine dioxide and its byproducts may have similar effects as chloramines.

4.3.9 Ultraviolet light: .See [POLICY STATEMENT ON ULTRAVIOLET LIGHT FOR TREATMENT OF PUBLIC WATER SUPPLIES](#).

4.3.10 Other disinfecting agents: Proposals for use of disinfecting agents other than those listed shall be approved by the reviewing authority prior to preparation of final plans and specification.

4.4 SOFTENING: The softening process selected must be based upon the mineral qualities of the raw water and the desired finished water quality in conjunction with requirements for disposal of sludge or brine waste, cost of plant, cost of chemicals and plant location. Applicability of the process chosen shall be demonstrated.

4.4.1 Lime or lime-soda process: Design standards for rapid mix, flocculation and sedimentation are in Section 4.1. Additional consideration must be given to the following process elements.

4.4.1.1 Hydraulics: When split treatment is used, the bypass line should be sized to carry total plant flow, and an accurate means of measuring and splitting the flow must be provided.

4.4.1.2 Aeration: Determinations should be made for the carbon dioxide content of the raw water. When concentrations exceed 10 mg/L, the economics of removal by aeration as opposed to removal with lime should be considered if it has been determined that dissolved oxygen in the finished water will not cause corrosion problems in the distribution system. (see Section 4.5).

4.4.1.3 Chemical feed point: Lime should be fed directly into the rapid mix basin.

- 4.4.1.4 Rapid mix:** Rapid mix basins must provide not more than 30 seconds detention time with adequate velocity gradients to keep the lime particles dispersed.
- 4.4.1.5 Stabilization:** Equipment for stabilization of water softened by the lime or lime-soda process is required. (see Section 4.8).
- 4.4.1.6 Sludge collection**
- a. Mechanical sludge removal equipment shall be provided in the sedimentation basin.
 - b. Sludge recycling to the rapid mix should be provided. If it is not, the reviewing authority must approve the point of recycle.
- 4.4.1.7 Sludge disposal:** Provisions must be included for proper disposal of softening sludges. (see Part 9).
- 4.4.1.8 Disinfection:** The use of excess lime shall not be considered an acceptable substitute for disinfection. (see Section 4.3)
- 4.4.1.9 Plant start-up:** The plant processes must be manually started following shut-down.
- 4.4.2 Cation exchange process:** Alternative methods of hardness reduction should be investigated when the sodium content and dissolved solids concentration is of concern.
- 4.4.2.1 Pre-treatment requirements:** Iron, manganese, or a combination of the two, should not exceed 0.3 mg/L in the water as applied to the ion exchange resin. Pre-treatment is required when the content of iron, manganese, or a combination of the two, is one milligram per liter or more. (see Section 4.6). Waters having 5 units or more turbidity should not be applied directly to the cation exchange softener.
- 4.4.2.2 Design:** The units may be of pressure or gravity type, of either an upflow or downflow design. Automatic regeneration based on volume of water softened should be used unless manual regeneration is justified and is approved by the reviewing authority. A manual override shall be provided on all automatic controls.
- 4.4.2.3 Exchange capacity:** The design capacity for hardness removal should not exceed 20,000 grains per cubic foot (46 kg/m³) when resin is regenerated with 0.3 pounds (0.14 kg) of salt per kgr of hardness removed.
- 4.4.2.4 Depth of resin:** The depth of the exchange resin should not be less than three feet.
- 4.4.2.5 Flow rates:** The rate of softening should not exceed seven gallons per minute per square foot of bed area (17 m/hr) and the backwash rate should be six to eight gallons per minute per square foot (14 - 20 m/hr) of bed area. Rate-of-flow controllers or the equivalent must be installed for the above purposes.

- 4.4.2.6 Freeboard:** The freeboard will depend upon the size and specific gravity of the resin and the direction of water flow. Generally, the washwater collector should be 24 inches above the top of the resin on downflow units.
- 4.4.2.7 Underdrains and supporting gravel:** The bottoms, strainer systems and support for the exchange resin shall conform to criteria provided for rapid rate gravity filters. (see Sections 4.2.1.6 and 4.2.1.7).
- 4.4.2.8 Brine distribution:** Facilities should be included for even distribution of the brine over the entire surface of both upflow and downflow units.
- 4.4.2.9 Cross-connection control:** Backwash, rinse and air relief discharge pipes shall be installed in such a manner as to prevent any possibility of back-siphonage.
- 4.4.2.10 Bypass piping and equipment:** Bypass must be provided around softening units to produce a blended water of desirable hardness. Totalizing meters must be installed on the bypass line and on each softener unit. The bypass line must have a shutoff valve and should have an automatic proportioning or regulating device. In some installations, it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.
- 4.4.2.11 Additional limitations:** Silica gel resins should not be used for waters having a pH above 8.4 or containing less than six milligrams per liter silica and should not be used when iron is present. When the applied water contains a chlorine residual, the cation exchange resin shall be a type that is not damaged by residual chlorine. Phenolic resin should not be used.
- 4.4.2.12 Sampling taps:** Smooth-nose sampling taps must be provided for the collection of representative samples. The taps shall be located to provide for sampling of the softener influent, effluent and blended water. The sampling taps for the blended water shall be at least 20 feet downstream from the point of blending. Petcocks are not acceptable as sampling taps. Sampling taps should be provided on the brine tank discharge piping.
- 4.4.2.13 Brine and salt storage tanks:**
- a. Salt dissolving or brine tanks and wet salt storage tanks must be covered and must be corrosion-resistant.
 - b. The make-up water inlet must be protected from back-siphonage. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank. The tanks should be provided with an automatic declining level control system on the make-up water line.
 - c. Wet salt storage basins must be equipped with manholes or hatchways for access and for direct dumping of salt from truck or railcar. Openings must be provided with raised curbs and watertight covers having overlapping edges similar to those required for finished water reservoirs. Each cover shall be hinged on one side, and shall have locking device.

- d. Overflows, where provided, must be protected with corrosion resistant screens and must terminate with either a turned down bend having a proper free fall discharge or a self-closing flap valve.
- e. Two wet salt storage tanks or compartments designed to operate independently should be provided.
- f. The salt shall be supported on graduated layers of gravel placed over a brine collection system.
- g. Alternative designs which are conducive to frequent cleaning of the wet salt storage tank may be considered.

4.4.2.14 Salt and brine storage capacity: Total salt storage should have sufficient capacity to store in excess of 1.5 carloads or truckloads of salt, and provide for at least 30 days of operation.

4.4.2.15 Brine pump or eductor: An eductor may be used to transfer brine from the brine tank to the softeners. If a pump is used, a brine measuring tank or means of metering should be provided to obtain proper dilution.

4.4.2.16 Stabilization: Refer to 4.8

4.4.2.17 Waste disposal: Suitable disposal must be provided for brine waste (See Part 9). Where the volume of spent brine must be reduced, consideration may be given to using a part of the spent brine for a subsequent regeneration.

4.4.2.18 Construction materials: Pipes and contact materials must be resistant to the aggressiveness of salt. Plastic and red brass are acceptable piping materials. Steel and concrete must be coated with a non-leaching protective coating which is compatible with salt and brine.

4.4.2.19 Housing: Bagged salt and Dry bulk salt storage shall be enclosed and separated from other operating areas in order to prevent damage to equipment.

4.4.3 Water quality test equipment: Test equipment for alkalinity, total hardness, carbon dioxide content, and pH should be provided to determine treatment effectiveness.

4.5 AERATION: Aeration may be used to help remove offensive tastes and odors due to dissolved gases from decomposing organic matter, or to reduce or remove objectionable amounts of carbon dioxide, hydrogen sulfide, etc., and to introduce oxygen to assist in iron and/or manganese removal. The packed tower aeration process is an aeration process applicable to removal of volatile organic contaminants.

4.5.1 Natural draft aeration: Design shall provide

- a. perforations in the distribution pan 3/16 to 1/2 inches in diameter, spaced 1 to 3 inches on centers to maintain a six inch water depth,
- b. for distribution of water uniformly over the top tray,
- c. discharge through a series of three or more trays with separation of trays not less than 12 inches,

- d. loading at a rate of 1 to 5 gallons per minute for each square foot of total tray area (2.5 - 12.5 m/hr),
- e. trays with slotted, heavy wire (1/2 inch openings) mesh or perforated bottoms,
- f. construction of durable material resistant to aggressiveness of the water and dissolved gases,
- g. protection from loss of spray water by wind carriage by enclosure with louvers sloped to the inside at a angle of approximately 45 degrees,
- h. protection from insects by 24-mesh screen.
- i. Provisions for continuous disinfection feed shall be provided after aeration.

4.5.2 Forced or induced draft aeration Devices shall be designed to

- a. include a blower with a weatherproof motor in a tight housing and screened enclosure,
- b. insure adequate counter current of air through the enclosed aerator column,
- c. exhaust air directly to the outside atmosphere,
- d. include a down-turned and 24-mesh screened air outlet and inlet,
- e. be such that air introduced in the column shall be as free from obnoxious fumes, dust, and dirt as possible,
- f. be such that sections of the aerator can be easily reached or removed for maintenance of the interior or installed in a separate aerator room,
- g. provide loading at a rate of 1 to 5 gallons per minute for each square foot of total tray area(2.5 - 12.5 m/hr), h. insure that the water outlet is adequately sealed to prevent unwarranted loss of air,
- h. discharge through a series of five or more trays with separation of trays not less than six inches or as approved by the reviewing authority,
- i. provide distribution of water uniformly over the top tray,
- j. be of durable material resistant to the aggressiveness of the water and dissolved gases.
- k. provide for continuous disinfection feed after aeration.

4.5.3 Spray aeration: Design shall provide

- a. a hydraulic head of between 5 - 25 feet,
- b. nozzles, with the size, number, and spacing of the nozzles being dependent on the flowrate, space, and the amount of head available,
- c. nozzle diameters in the range of 1 to 1.5 inches to minimize clogging,
- d. an enclosed basin to contain the spray. Any openings for ventilation, etc. must be protected with a 24-mesh screen.
- e. for continuous disinfection feed after aeration.

4.5.4 Pressure aeration: Pressure aeration may be used for oxidation purposes only if pilot plant study indicates the method is applicable; it is not acceptable for removal of dissolved gases. Filters following pressure aeration must have adequate exhaust devices for release of air. Pressure aeration devices shall be designed to

- a. give thorough mixing of compressed air with water being treated,
- b. provide screened and filtered air, free of obnoxious fumes, dust, dirt and other contaminants.

4.5.5 Packed tower aeration: Packed tower aeration (PTA) which is also known as air stripping involves passing water down through a column of packing material while pumping air counter-currently up through the packing. PTA is used for the removal of volatile organic chemicals, trihalomethanes, carbon dioxide, and radon. Generally, PTA is feasible for compounds with a Henry's Constant greater than 100 atm mol/mol at 120C, but not normally feasible for removing compounds with a Henry's Constant less than 10. For values between 10 and 100, PTA may be feasible but should be extensively evaluated using pilot studies. Values for Henry's Constant should be discussed with the reviewing agency prior to final design.

4.5.5.1 Process design

- a. Process design methods for PTA involve the determination of Henry's Constant for the contaminant, the mass transfer coefficient, air pressure drop and stripping factor. The applicant shall provide justification for the design parameters selected (i.e. height and diameter of unit, air to water ratio, packing depth, surface loading rate, etc.).

Pilot plant testing may be required: The pilot test shall evaluate a variety of loading rates and air to water ratios at the peak contaminant concentration. Special consideration should be given to removal efficiencies when multiple contaminations occur. Where there is considerable past performance data on the contaminant to be treated and there is a concentration level similar to previous projects, the reviewing authority may approve the process design based on use of appropriate calculations without pilot testing. Proposals of this type must be discussed with the reviewing authority prior to submission of any permit applications.

- b. The tower shall be designed to reduce contaminants to below the maximum contaminant level (MCL) and to the lowest practical level.
- c. The ratio of the column diameter to packing diameter should be at least 7:1 for the pilot unit and at least 10:1 for the full scale tower. The type and size of the packing used in the full scale unit shall be the same as that used in the pilot work.
- d. The minimum volumetric air to water ratio at peak water flow should be 25:1. The maximum air to water ratio for which credit will be given is 80:1.
- e. The design should consider potential fouling problems from calcium carbonate and iron precipitation and from bacterial growth. It may be necessary to provide pretreatment. Disinfection capability shall be provided prior to and after PTA.

- f. The effects of temperature should be considered since a drop in water temperature can result in a drop in contaminant removal efficiency.

4.5.5.2 Materials of construction

- a. The tower can be constructed of stainless steel, concrete, aluminum, fiberglass or plastic. Uncoated carbon steel is not recommended because of corrosion. Towers constructed of light-weight materials should be provided with adequate support to prevent damage from wind.
- b. Packing materials shall be resistant to the aggressiveness of the water, dissolved gases and cleaning materials and shall be suitable for contact with potable water.

4.5.5.3 Water flow system

- a. Water should be distributed uniformly at the top of the tower using spray nozzles or orifice-type distributor trays that prevent short circuiting. For multi-point injection, one injection point for every 30 in² (190 cm²) of tower crosssectional area is recommended.
- b. A mist eliminator shall be provided above the water distributor system.
- c. A side wiper redistribution ring shall be provided at least every 10 feet in order to prevent water channeling along the tower wall and short circuiting.
- d. Sample taps shall be provided in the influent and effluent piping.
- e. The effluent sump, if provided, shall have easy access for cleaning purposes and be equipped with a drain valve. The drain shall not be connected directly to any storm or sanitary sewer.
- f. A blow-off line should be provided in the effluent piping to allow for discharge of water/chemicals used to clean the tower.
- g. The design shall prevent freezing of the influent riser and effluent piping when the unit is not operating. If piping is buried, it shall be maintained under positive pressure.
- h. The water flow to each tower shall be metered.
- i. An overflow line shall be provided which discharges 12 to 14 inches above a splash pad or drainage inlet. Proper drainage shall be provided to prevent flooding of the area.
- j. Butterfly valves may be used in the water effluent line for better flow control, as well as to minimize air
- k. entrainment.
- l. Means shall be provided to prevent flooding of the air blower.
- m. The water influent pipe should be supported separately from the tower's main structural support.

4.5.5.4 Air flow system

- a. The air inlet to the blower and the tower discharge vent shall be downturned and protected with a non-corrodible 24-mesh screen to prevent contamination from extraneous matter. It is recommended that a 4-mesh screen also be installed prior to the 24-mesh screen on the air inlet system.
- b. The air inlet shall be in a protected location.
- c. An air flow meter shall be provided on the influent air line or an alternative method to determine the air flow shall be provided.
- d. A positive air flow sensing device and a pressure gauge must be installed on the air influent line. The positive air flow sensing device must be a part of an automatic control system which will turn off the influent water if positive air flow is not detected. The pressure gauge will serve as an indicator of fouling buildup.
- e. A backup motor for the air blower must be readily available.

4.5.5.5 Other features that shall be provided

- a. A sufficient number of access ports with a minimum diameter of 24 inches to facilitate inspection, media replacement, media cleaning and maintenance of the interior.
- b. A method of cleaning the packing material when fouling may occur.
- c. Tower effluent collection and pumping wells constructed to clearwell standards.
- d. Provisions for extending the tower height without major reconstruction.
- e. An acceptable alternative supply must be available during periods of maintenance and operation interruptions. No bypass shall be provided unless specifically approved by the reviewing agency.
- f. Disinfection application points both ahead of and after the tower to control biological growth.
- g. Disinfection and adequate contact time after the water has passed through the tower and prior to the distribution system.
- h. Adequate packing support to allow free flow of water and to prevent deformation with deep packing heights.
- i. Operation of the blower and disinfectant feeder equipment during power failures.
- j. Adequate foundation to support the tower and lateral support to prevent overturning due to wind loading.
- k. Fencing and locking gate to prevent vandalism.

- I. An access ladder with safety cage for inspection of the aerator including the exhaust port and de-mister.
- m. Electrical interconnection between blower, disinfectant feeder and well pump.

4.5.5.6 Environmental factors

- a. The applicant must contact the appropriate air quality office to determine if permits are required under the Clean Air Act.
- b. Noise control facilities should be provided on PTA systems located in residential areas.

4.5.6 Other methods of aeration: Other methods of aeration may be used if applicable to the treatment needs. Such methods include but are not restricted to spraying, diffused air, cascades and mechanical aeration. The treatment processes must be designed to meet the particular needs of the water to be treated and are subject to the approval of the reviewing authority.

4.5.7 Protection of aerators: All aerators except those discharging to lime softening or clarification plants shall be protected from contamination by birds, insects, wind borne debris, rainfall and water draining off the exterior of the aerator.

4.5.8 Disinfection: Groundwater supplies exposed to the atmosphere by aeration must receive chlorination as the minimum additional treatment.

4.5.9 Bypass: A bypass should be provided for all aeration units except those installed to comply with maximum contaminant levels.

4.5.10 Corrosion control: The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary. (see Section 4.8).

4.5.11 Quality control: Equipment should be provided to test for DO, pH, and temperature to determine proper functioning of the aeration device. Equipment to test for iron, manganese, and carbon dioxide should also be considered.

4.5.12 Redundancy: Redundant equipment shall be provided for units installed to comply with Safe Drinking Water Act primary contaminants, unless otherwise approved by the reviewing authority.

4.6 IRON AND MANGANESE CONTROL: Iron and manganese control, as used herein, refers solely to treatment processes designed specifically for this purpose. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment processes must meet specific local conditions as determined by engineering investigations, including chemical analyses of representative samples of water to be treated, and receive the approval of the reviewing authority. It may be necessary to operate a pilot plant in order to gather all information pertinent to the design. Consideration should be given to adjusting pH of the raw water to optimize the chemical reaction. Testing equipment and sampling taps shall be provided as outlined in Sections [2.8](#) and [2.10](#).

4.6.1 Removal by oxidation, detention and filtration

4.6.1.1 Oxidation: Oxidation may be by aeration, as indicated in Section 4.5, or by chemical oxidation with chlorine, potassium permanganate, sodium permanganate, ozone or chlorine dioxide.

4.6.1.2 Detention

a. Reaction – A minimum detention time of 30 minutes shall be provided following aeration to insure that the oxidation reactions are as complete as possible. This minimum detention may be omitted only where a pilot plant study indicates no need for detention. The detention basin may be designed as a holding tank without provisions for sludge collection but with sufficient baffling to prevent short circuiting.

b. Sedimentation – Sedimentation basins shall be provided when treating water with high iron and/or manganese content, or where chemical coagulation is used to reduce the load on the filters. Provisions for sludge removal shall be made.

4.6.1.3 Filtration: Filters shall be provided and shall conform to Section 4.2.

4.6.2 Removal by the lime-soda softening process: See [Section 4.4.1](#).

4.6.3 Removal by manganese coated media filtration: This process, consists of a continuous or batch feed of potassium permanganate to the influent of a manganese coated media filter.

- a. Provisions should be made to apply the permanganate as far ahead of the filter as practical and to a point immediately before the filter.
- b. Other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce the amount of the chemical oxidant needed.
- c. An anthracite media cap of at least six inches or more as required by the reviewing authority shall be provided over manganese coated media.
- d. Normal filtration rate is three gallons per minute per square foot (7.2 m/hr).
- e. Normal wash rate is 8 to 10 gallons per minute per square foot (20 - 24 m/hr) with manganese greensand and 15 to 20 gallons per minute (37 - 49 m/hr) with manganese coated media.
- f. Air washing should be provided.
- g. Sample taps shall be provided
 1. for the raw water,
 2. immediately ahead of filtration,
 3. at the filter effluent, and
 4. should be provided at points between the anthracite media and the manganese coated media.

4.6.4 Removal by ion exchange: This process of iron and manganese removal should not be used for water containing more than 0.3 milligrams per liter of iron, manganese or

combination thereof. This process is not acceptable where either the raw water or wash water contains dissolved oxygen or other oxidants.

4.6.5 Biological removal: Biofiltration to remove manganese and/or iron requires on-site piloting to establish effectiveness. The final filter design shall be based on the on-site pilot plant studies and shall comply with all applicable portions of section 4.2.7. Continuous disinfection shall be provided for the finished water.

4.6.6 Sequestration by polyphosphates: This process shall not be used when iron, manganese or combination thereof exceeds 1.0 mg/L. The total phosphate applied shall not exceed 10 mg/L as PO₄. Where phosphate treatment is used, satisfactory chlorine residuals shall be maintained in the distribution system. Possible adverse effects on corrosion must be addressed when phosphate addition is proposed for iron sequestering. Polyphosphate treatment may be less effective for sequestering manganese than for iron.

- a. Feeding equipment shall conform to the requirements of Part 5.
- b. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L free chlorine residual unless the phosphate is not able to support bacterial growth and the phosphate is being fed from the covered shipping container. Phosphate solutions having a pH of 2.0 or less may also be exempted from this requirement by the reviewing authority.
- c. Polyphosphates shall not be applied ahead of iron and manganese removal treatment. The point of application shall be prior to any aeration, oxidation or disinfection if no iron or manganese removal treatment is provided.
- d. The phosphate feed point shall be located as far ahead of the oxidant feed point as possible.

4.6.7 Sequestration by sodium silicates: Sodium silicate sequestration of iron and manganese is appropriate only for groundwater supplies prior to air contact. On-site pilot tests are required to determine the suitability of sodium silicate for the particular water and the minimum feed needed. Rapid oxidation of the metal ions such as by chlorine or chlorine dioxide must accompany or closely precede the sodium silicate addition. Injection of sodium silicate more than 15 seconds after oxidation may cause detectable loss of chemical efficiency. Dilution of feed solutions much below five per cent silica as SiO₂ should also be avoided for the same reason. Sodium silicate treatment may be less effective for sequestering manganese than for iron.

- a. Sodium silicate addition is applicable to waters containing up to 2 mg/l of iron, manganese or combination thereof.
- b. Chlorine residuals shall be maintained throughout the distribution system to prevent biological breakdown of the sequestered iron.
- c. The amount of silicate added shall be limited to 20 mg/l as SiO₂, but the amount of added and naturally occurring
- d. silicate shall not exceed 60 mg/l as SiO₂
- e. Feeding equipment shall conform to the requirements of Part 5.

- f. Sodium silicate shall not be applied ahead of iron or manganese removal treatment.

4.6.8 Sampling taps: Smooth-nosed sampling taps shall be provided for control purposes. Taps shall be located on each raw water source, each treatment unit influent and each treatment unit effluent.

4.6.9 Testing equipment shall be provided for all plants.

- a. The equipment should have the capacity to accurately measure the iron content to a minimum of 0.1 mg/L and the manganese content to a minimum of 0.05 mg/L.
- b. Where polyphosphate sequestration is practiced, appropriate phosphate testing equipment shall be provided.

4.7 FLUORIDATION: Sodium fluoride, sodium silicofluoride and fluorosilicic acid shall conform to the applicable AWWA standards and ANSI/NSF Standard 60. Other fluoride compounds which may be available must be approved by the reviewing authority.

4.7.1 Fluoride compound storage: Fluoride chemicals should be isolated from other chemicals to prevent contamination. Compounds shall be stored in covered or unopened shipping containers and should be stored inside a building. Unsealed storage units for fluorosilicic acid should be vented to the atmosphere at a point outside any building. The vents to atmosphere shall be provided with a corrosion resistant 24 mesh screen. Bags, fiber drums and steel drums should be stored on pallets.

4.7.2 Chemical feed equipment and methods: In addition to the requirements in [Part 5](#), fluoride feed equipment shall meet the following requirements:

- a. scales, loss-of-weight recorders or liquid level indicators, as appropriate, accurate to within five percent of the average daily change in reading shall be provided for chemical feeds,
- b. feeders shall be accurate to within five percent of any desired feed rate,
- c. fluoride compound shall not be added before lime-soda softening or ion exchange softening,
- d. the point of application of fluorosilicic acid, if into a horizontal pipe, shall be in the lower half of the pipe,
- e. a fluoride solution shall be applied by a positive displacement pump having a stroke rate not less than 20 strokes per minute, and at a feed rate not less than 20 percent of the rated capacity of the feed pump,
- f. A spring opposed diaphragm type anti-siphon device shall be provided for all fluoride feed lines and dilution water lines,
- g. except for constant flow systems, a device to measure the flow of water to be treated is required,
- h. the dilution water pipe shall terminate at least two pipe diameters above the solution tank,
- i. water used for sodium fluoride dissolution shall be softened if hardness exceeds 75 mg/l as calcium carbonate,

- j. fluoride solutions shall be injected at a point of continuous positive pressure or a suitable air gap provided,
- k. the electrical outlet used for the fluoride feed pump should have a nonstandard receptacle and shall be interconnected with the well or service pump, or have flow pacing as allowed by the reviewing authority.
- l. saturators should be of the upflow type and be provided with a meter and backflow protection on the makeup water line,
- m. consideration shall be given to providing a separate room for fluorosilicic acid storage and feed.

4.7.3 Secondary controls: Secondary control systems for fluoride chemical feed devices shall be provided as a means of reducing the possibility for overfeed; these may include flow or pressure switches, break boxes, or other devices.

4.7.4 Protective equipment: Personal protective equipment as outlined in Section 5.3.4 shall be provided for operators handling fluoride compounds. Deluge showers and eye wash devices shall be provided at all fluorosilicic acid installations.

4.7.5 Dust control

- a. Provision must be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust which may enter the room in which the equipment is installed. The enclosure shall be provided with an exhaust fan and dust filter which place the hopper under a negative pressure. Air exhausted from fluoride handling equipment shall discharge through a dust filter to the outside atmosphere of the building.
- b. Provision shall be made for disposing of empty bags, drums or barrels in a manner which will minimize exposure to fluoride dusts. A floor drain should be provided to facilitate the hosing of floors.

4.7.6 Testing equipment: Equipment shall be provided for measuring the quantity of fluoride in the water. Such equipment shall be subject to the approval of the reviewing authority.

4.8 STABILIZATION: Water that is unstable due either to natural causes or to subsequent treatment shall be stabilized. Treated water should be routinely evaluated to ensure that water quality parameters and characteristics are optimized to obtain the desired water stability throughout the distribution system of a water supply.

4.8.1 Carbon dioxide addition

a. Recarbonation basin design should provide

1. a total detention time of twenty minutes,
2. two compartments, with a depth that will provide a diffuser submergence of not less than 7.5 feet nor greater submergence than recommended by the manufacturer as follows:
 - a. a mixing compartment having a detention time of at least three minutes,

- b. a reaction compartment.
- c. The practice of on-site generation of carbon dioxide is discouraged.
- d. Where liquid carbon dioxide is used, adequate precautions must be taken to prevent carbon dioxide from entering the plant from the recarbonation process. In addition, consideration should be given to the installation of a carbon dioxide alarm system with light and audio warning, especially in low areas.
- e. Recarbonation tanks shall be located outside or be sealed and vented to the outside with adequate seals and adequate purge flow of air to ensure workers safety.
- f. Provisions shall be made for draining the recarbonation basin and removing sludge.

4.8.2 Acid addition

- a. Feed equipment shall conform to Part 5.
- b. Adequate precautions shall be taken for operator safety, such as not adding water to the concentrated acid. (See Sections 5.3 and 5.4).

4.8.3 Phosphates: The feeding of phosphates may be applicable for sequestering calcium, for corrosion control, and in conjunction with alkali feed following ion exchange softening.

- a. Feed equipment shall conform to Part 5.
- b. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L free chlorine residual unless the phosphate is not able to support bacterial growth and the phosphate is being fed from the covered shipping container. Phosphate solutions having a pH of 2.0 or less may also be exempted from this requirement by the reviewing authority.
- c. Satisfactory chlorine residuals shall be maintained in the distribution system when phosphates are used.

4.8.4 "Split treatment": Under some conditions, a lime-softening water treatment plant can be designed using "split treatment" in which raw water is blended with lime-softened water to partially stabilize the water prior to secondary clarification and filtration. Treatment plants designed to utilize "split treatment" should also contain facilities for further stabilization by other methods.

4.8.5 Alkali feed: Water with low alkalinity or pH should be treated with an alkali chemical.

4.8.6 Carbon dioxide reduction by aeration: The carbon dioxide content of an aggressive water may be reduced by aeration. Aeration devices shall conform to Section 4.5.

4.8.7 Other treatment: Other treatment for controlling corrosive waters by the use of calcium hydroxide, sodium silicate and sodium bicarbonate may be used where necessary. Any proprietary compound must receive the specific approval of the reviewing authority before use. Chemical feeders shall be as required in [Part 5](#).

4.8.8 Water unstable due to biochemical action in distribution system: Unstable water resulting from the bacterial decomposition of organic matter in water (especially in dead end mains), the biochemical action within tubercles, and the reduction of sulfates to sulfides should be prevented by the maintenance of a free and/or combined chlorine residual throughout the distribution system.

4.8.9 Control: Laboratory equipment shall be provided for determining the effectiveness of stabilization treatment.

4.9 TASTE AND ODOR CONTROL: Provisions shall be made for the control of taste and odor at all surface water treatment plants where needed. Chemicals shall be added to assure adequate contact time for effective and economical use of the chemicals. Where severe taste and odor problems are encountered, in-plant and/or pilot plant studies should be considered.

4.9.1 Flexibility: Plants treating water that is known to have taste and odor problems should be provided with equipment that makes several of the control processes available so that the operator will have flexibility in operation.

4.9.2 Chlorination: Chlorination can be used for the removal of some objectionable odors. Excessive potential disinfection byproduct production shall be investigated bench-scale testing prior to design.

4.9.3 Chlorine dioxide: Chlorine dioxide has been generally recognized as a treatment for tastes caused by industrial wastes, such as phenols. However, chlorine dioxide can be used in the treatment of any taste and odor that is treatable by an oxidizing compound. Provisions shall be made for proper storing and handling of the sodium chlorite, so as to eliminate any danger of explosion.

4.9.4 Powdered activated carbon

- a. Powdered activated carbon should be added as early as possible in the treatment process to provide maximum contact time. Flexibility to allow the addition of carbon at several points is preferred. Activated carbon should not be applied near the point of chlorine or other oxidant application.
- b. The carbon can be added as a pre-mixed slurry or by means of a dry-feed machine as long as the carbon is properly wetted.
- c. Continuous agitation or resuspension equipment shall be provided to keep the carbon from depositing in the slurry storage tank.
- d. Provision shall be made for adequate dust control.
- e. The required rate of feed of carbon in a water treatment plant depends upon the tastes and/or odors involved, but provision should be made for adding from 0.1 milligrams per liter to at least 40 milligrams per liter.

- f. Powdered activated carbon shall be handled as a potentially combustible material. It should be stored in a building
- g. or compartment as nearly fireproof as possible. Other chemicals should not be stored in the same compartment. A separate room should be provided for carbon feed installations. Carbon feeder rooms should be equipped with explosion-proof electrical outlets, lights, and motors.

4.9.5 Granular activated carbon: Replacement of anthracite with GAC may be considered as a control measure for geosmin and methyl isoborneol (MIB) taste and odors from algae blooms. Demonstration studies may be required by the reviewing authority. [See Section 4.2.1.6 for application within filters.](#)

4.9.6 Copper sulfate and other copper compounds: Continuous or periodic treatment of water with copper compounds to kill algae or other growths shall be controlled to prevent copper in excess of 1.0 milligrams per liter as copper in the plant effluent or distribution system. Care shall be taken to assure an even distribution of the chemical within the treatment area. Necessary approval and/or permits shall be obtained prior to application, if required. Consult the responsible Regulatory Agencies (e.g., Fish and Wildlife agencies or Department of Natural Resources) before making applications to public waters.

4.9.7 Aeration: See [Section 4.5.](#)

4.9.8 Potassium permanganate: Application of potassium permanganate may be considered, providing the treatment shall be designed so that the products of the reaction are not visible in the finished water.

4.9.9 Ozone: Ozonation can be used as a means of taste and odor control. Adequate contact time must be provided to complete the chemical reactions involved. Ozone is generally more desirable for treating water with high threshold odors. ([See Section 4.3.7](#))

4.9.10 Other methods: The decision to use any other methods of taste and odor control should be made only after careful laboratory and/or pilot plant tests and on consultation with the reviewing authority.

4.10 MICROSCREENING: A microscreen is a mechanical supplement of treatment capable of removing suspended matter from the water by straining. It may be used to reduce nuisance organisms and organic loadings. It shall not be used in place of

- a. filtration, when filtration is necessary to provide a satisfactory water, or
- b. coagulation, in the preparation of water for filtration.

4.10.1 Design

a. shall give due consideration to

1. nature of the suspended matter to be removed,
2. corrosiveness of the water,
3. effect of chlorination, when required as pre-treatment,
4. duplication of units for continuous operation during equipment maintenance,

5. automated backflushing operation when used in conjunction with microfiltration treatment.

b. shall provide

1. a durable, corrosion-resistant screen,
2. by-pass arrangements,
3. protection against back-siphonage when potable water is used for washing,
4. proper disposal of wash waters. (See Part 9)

PART 5 - CHEMICAL APPLICATION

5.0 GENERAL: No chemicals shall be applied to treat drinking waters unless specifically permitted by the reviewing authority.

5.0.1 Plans and specifications: Plans and specifications shall be submitted for review and approval, as provided for in Part 2, and shall include

- a. descriptions of feed equipment, including maximum and minimum feed ranges,
- b. location of feeders, piping layout and points of application,
- c. storage and handling facilities,
- d. operating and control procedures including proposed application rates,
- e. descriptions of testing equipment, and
- f. system including all tanks with capacities, (with drains, overflows, and vents), feeders, transfer pumps, connecting piping, valves, points of application, backflow prevention devices, air gaps, secondary containment, and safety eye washes and showers.

5.0.2 Chemical application: Chemicals shall be applied to the water at such points and by such means as to

- a. assure maximum efficiency of treatment,
- b. assure maximum safety to consumer,
- c. provide maximum safety to operators,
- d. assure satisfactory mixing of the chemicals with the water,
- e. provide maximum flexibility of operation through various points of application, when appropriate, and
- f. prevent backflow or back-siphonage between multiple points of feed through common manifolds.

5.0.3 General equipment design: General equipment design shall be such that

- a. feeders will be able to supply, at all times, the necessary amounts of chemicals at an accurate rate, throughout the range of feed,

- b. chemical-contact materials and surfaces are resistant to the aggressiveness of the chemical solution,
- c. corrosive chemicals are introduced in such a manner as to minimize potential for corrosion,
- d. chemicals that are incompatible are not stored or handled together,
- e. all chemicals are conducted from the feeder to the point of application in separate conduits,
- f. chemical feeders are as near as practical to the feed point,
- g. chemical feeders and pumps shall operate at no lower than 20 per cent of the feed range unless two fully independent adjustment mechanisms such as pump pulse rate and stroke length are fitted when the pump shall operate at no lower than 10 percent of the rated maximum, and
- h. gravity may be used where practical.

5.0.4 Chemical Information: For each chemical the information submitted shall include:

- a. specifications for the chemical to be used,
- b. purpose of the chemical,
- c. proposed minimum non-zero, average and maximum dosages, solution strength or purity (as applicable), and specific gravity or bulk density, and
- d. method for independent calculation of amount fed daily.

5.1 FEED EQUIPMENT

5.1.1 Feeder redundancy

- a. Where a chemical feed and booster pump is necessary for the protection of the supply, such as chlorination, coagulation or other essential processes, a standby unit or a combination of units of sufficient size to meet capacity shall be provided to replace the largest unit when out of service, and the reviewing authority may require that more than one be installed.
- b. A separate feeder shall be used for each chemical applied.
- c. Spare parts shall be available on site for all feeders and chemical booster pumps to replace parts which are subject to wear and damage.

5.1.2 Control

- a. Feeders may be manually or automatically controlled. Automatic controls shall be designed so as to allow override by manual controls.
- b. Chemical feed rates shall be proportional to the flow stream being dosed.
- c. A means to measure the flow stream being dosed shall be provided in order to determine chemical feed rates.
- d. Provisions shall be made for measuring the quantities of chemicals used.
- e. Weighing scales

1. shall be provided for weighing cylinders at all plants utilizing chlorine gas,
 2. shall be required for fluoride solution fed from supply drums or carboys, and
 3. should be provided for volumetric dry chemical feeders,
 4. shall be capable of providing reasonable precision in relation to average daily dose.
- f. Where conditions warrant, for example with rapidly fluctuating intake turbidity, coagulant and coagulant aid addition may be made according to turbidity, streaming current or other sensed parameter.

5.1.3 Dry chemical feeders: Dry chemical feeders shall

- a. measure chemicals volumetrically (see 5.1.2.e.3) or gravimetrically,
- b. provide adequate solution/slurry water and agitation of the chemical at the point of placing in solution/slurry, and
- c. completely enclose chemicals to prevent emission of dust to the operating room.

5.1.4 Positive displacement solution feed pumps

- a. Positive displacement type solution feed pumps should be used to feed liquid chemicals, but shall not be used to feed chemical slurries.
- b. Pumps must be capable of operating at the required maximum rate against the maximum head conditions found at the point of injection.
- c. calibration tubes or mass flow monitors which allow for direct physical measurement of actual feed rates should be provided, and
- d. a pressure relief valve should be provided on the pump discharge line.

5.1.5 Liquid chemical feeders – siphon control: Liquid chemical feeders shall be such that chemical solutions cannot be siphoned or overfed into the water supply, by

- a. assuring discharge at a point of positive pressure, or
- b. providing vacuum relief, or
- c. providing a suitable air gap, or anti-siphon device, or
- d. providing other suitable means or combinations as necessary.

5.1.6 Cross-connection control: Cross-connection control shall be provided to assure that

- a. the service water lines discharging to liquid storage tanks shall be properly protected from backflow as required by the reviewing authority,
- b. chemical solutions or slurries cannot be siphoned through liquid chemical feeders into the water supply as required in Section 5.1.5, and
- c. no direct connection exists between any sewer and a drain or overflow from the liquid chemical feeder, liquid storage chamber or tank by providing that all drains terminate at least six inches or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit or waste receptacle.

- d. In the absence of other cross connection control measures, separate day tanks and feeders shall be provided for chemical feed systems that have feed points at both unfiltered and filtered water locations such that all unfiltered water feed points are fed from one day tank and feeder, and that all filtered water feed points are fed from another day tank and feeder.

5.1.7 Chemical feed equipment location: Chemical feed equipment

- a. shall be readily accessible for servicing, repair, and observation of operation,
- b. should be located in a separate room where wherever hazards and dust problems may exist, and
- c. should be conveniently located near points of application to minimize length of feed lines.

5.1.8 In-plant water supply: In-plant water supply shall be:

- a. ample in quantity and adequate in pressure,
- b. provided with means for measurement when preparing specific solution concentrations by dilution,
- c. properly treated for hardness, when necessary,
- d. properly protected against backflow, and
- e. obtained from the finished water supply, or from a location sufficiently downstream of any chemical feed point to assure adequate mixing.

5.1.9 Storage of chemicals

a. Space

- 1. at least 30 days of chemical supply,
 - 2. convenient and efficient handling of chemicals,
 - 3. dry storage conditions, and
 - 4. a minimum storage volume of 1.5 truck loads where purchase is by truck load lots.
- b. Storage tanks and pipelines for liquid chemicals shall be specified for use with individual chemicals and not used for different chemicals. Offloading areas shall be clearly labeled to prevent accidental cross-contamination.
 - c. Chemicals shall be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved storage unit.
 - d. Liquid chemical storage tanks shall
 - 1. have a liquid level indicator, and
 - 2. have an overflow and a receiving basin capable of receiving accidental spills or overflows without uncontrolled discharge; a common receiving basin may be provided for each group of compatible chemicals, that provides sufficient containment volume to prevent accidental discharge in the event of failure of the largest tank.

5.1.10 Bulk liquid storage tanks

- a. A means which is consistent with the nature of the chemical stored shall be provided in a liquid storage tank to maintain a uniform chemical strength. Continuous agitation shall be provided to maintain slurries in suspension.
- b. A means to assure continuity of chemical supply while servicing a liquid storage tank shall be provided.
- c. Means shall be provided to measure the liquid level in the liquid storage tank.
- d. Liquid storage tanks shall be kept covered. Large liquid storage tanks with access openings shall have such openings curbed and fitted with overhanging covers.
- e. Subsurface locations for liquid storage tanks shall
 1. be free from sources of possible contamination, and
 2. assure positive drainage away from the area for ground waters, accumulated water, chemical spills and overflows.
- f. **Overflow pipes, when provided, shall**
 1. be turned downward, with the end screened,
 2. have a free fall discharge, and
 3. be located where noticeable.
- g. Liquid storage tanks must be vented, but not through vents in common with day tanks. Acid storage tanks shall be vented to the outside atmosphere.
- h. Each liquid storage tank shall be provided with a valved drain,
- i. Each liquid storage tank shall be protected against cross-connections,
- j. Liquid storage tanks shall be located and secondary containment provided so that chemicals from equipment failure, spillage or accidental drainage shall not enter the water in conduits, treatment or storage basins. Secondary containment volumes shall be able to hold the volume of the largest storage tank. Piping shall be designed to minimize or contain chemical spills in the event of pipe ruptures.

5.1.11 Day tanks

- a. Day tanks shall be provided where bulk storage of liquid chemical is provided, however the reviewing authority may allow chemicals to be fed directly from shipping containers no larger than 55 gallons.
- b. Day tanks shall meet all the requirements of Section 5.1.10, except that shipping containers do not require f. (overflow pipes) and h. (drains).
- c. Day tanks should hold no more than a 30 hour supply.
- d. Day tanks shall be scale-mounted, or have a calibrated gauge painted or mounted on the side if liquid level can be observed in a gauge tube or through translucent sidewalls of the tank. In opaque tanks, a gauge rod may be used.
- e. Except for fluosilicic acid, hand pumps may be provided for transfer from a shipping container. A tip rack may be used to permit withdrawal into a bucket from a spigot.

Where motor-driven transfer pumps are provided, a liquid level limit switch shall be provided.

- f. A means which is consistent with the nature of the chemical solution shall be provided to maintain uniform chemical strength in a day tank. Continuous agitation shall be provided to maintain chemical slurries in suspension.
- g. Tanks and tank refilling line entry points shall be clearly labeled with the name of the chemical contained.
- h. Filling of day tanks shall not be automated, unless otherwise authorized by the reviewing authority.

5.1.12 Feed lines

a. should be as short as possible, and

- 1. of durable, corrosion-resistant material,
- 2. easily accessible throughout the entire length, and
- 3. readily cleanable;

b. shall be protected from freezing;

- c. should slope upward from the chemical source to the feeder when conveying gases;
- d. shall be designed consistent with scale-forming or solids depositing properties of the water, chemical, solution or mixtures conveyed; and
- e. should be color coded and labeled.

5.1.13 Handling

- a. Carts, elevators and other appropriate means shall be provided for lifting chemical containers to minimize excessive lifting by operators.
- b. Provisions shall be made for disposing of empty bags, drums, carboys, or barrels by an approved procedure which will minimize exposure to dusts.
- c. Provisions shall be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers, in such a way as to minimize the quantity of dust which may enter the room in which the equipment is installed. Control should be provided by use of
 - 1. vacuum pneumatic equipment or closed conveyor systems,
 - 2. facilities for emptying shipping containers in special enclosures, and/or
 - 3. exhaust fans and dust filters which put the storage hoppers or bins under negative pressure.
- d. Provision shall be made for measuring quantities of chemicals used to prepare feed solutions.

5.1.14 Housing

- a. Floor surfaces shall be smooth and impervious, slip-proof and well drained.

- b. Vents from feeders, storage facilities and equipment exhaust shall discharge to the outside atmosphere above grade and remote from air intakes.

5.2 CHEMICALS

5.2.1 Shipping containers: Chemical shipping containers shall be fully labeled to include

- a. chemical name, purity and concentration, and
- b. supplier name and address.

5.2.2 Specifications: Chemicals shall meet the appropriate ANSI/AWWA standards and/or ANSI/NSF Standard 60.

5.2.3 Assay: Provisions may be required for assay of chemicals delivered.

5.3 OPERATOR SAFETY

5.3.1 Ventilation: Special provisions shall be made for ventilation of chlorine feed and storage rooms.

5.3.2 Respiratory protection equipment: Respiratory protection equipment, meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) shall be available where chlorine gas is handled, and shall be stored at a convenient heated location, but not inside any room where chlorine is used or stored. The units shall use compressed air, have at least a 30 minute capacity, and be compatible with or exactly the same as units used by the fire department responsible for the plant.

5.3.3 Chlorine gas leak detection: A bottle of concentrated ammonium hydroxide (56 per cent ammonia solution) shall be available for chlorine leak detection; where ton containers are used, a leak repair kit approved by the Chlorine Institute shall be provided. Where pressurized chlorine gas is present, continuous chlorine leak detection equipment is required and shall be equipped with both an audible alarm and a warning light.

5.3.4 Other protective equipment:

- a. At least one pair of rubber gloves, a dust respirator of a type certified by NIOSH for toxic dusts, an apron or other protective clothing and goggles or face mask shall be provided for each operator as required by the reviewing authority. A deluge shower and eye washing device shall be installed where strong acids and alkalis are used or stored.
- b. A water holding tank that will allow water to come to room temperature must be installed in the water line feeding the deluge shower and eye washing device. Other methods of water tempering will be considered on an individual basis.
- c. Other protective equipment should be provided as necessary.

5.4 SPECIFIC CHEMICALS

5.4.1 Chlorine gas

- a. Chlorine gas feed and storage shall be enclosed and separated from other operating areas. The chlorine room shall be
 1. provided with a shatter resistant inspection window installed in an interior wall,

2. constructed in such a manner that all openings between the chlorine room and the remainder of the plant are sealed, and
 3. provided with doors equipped with panic hardware, assuring ready means of exit and opening outward only to the building exterior.
- b.** Full and empty cylinders of chlorine gas shall be
1. isolated from operating areas,
 2. restrained in position to prevent upset,
 3. stored in locked and secure rooms separate from ammonia storage, and
 4. protected from direct sunlight or exposure to excessive heat.
- c.** Where chlorine gas is used, the room shall be constructed to provide the following:
1. each chlorine room shall have a ventilating fan with a capacity which provides one complete air change per minute when the room is occupied; where this is not appropriate due to the size of the room a lesser rate may be considered,
 2. the ventilating fan shall take suction near the floor as far as practical from the door and air inlet, with the point of discharge so located as not to contaminate air inlets to any rooms or structures,
 3. air inlets shall be through corrosion resistant louvers near the ceiling,
 4. louvers for chlorine room air intake and exhaust shall facilitate airtight closure,
 5. separate switches for the ventilating fan and for the lights shall be located outside of the chlorine room and at the inspection window. Outside switches shall be protected from vandalism. A signal light indicating ventilating fan operation shall be provided at each entrance when the fan can be controlled from more than one point,
 6. vents from feeders and storage shall be screened and shall discharge to the outside atmosphere, above grade,
 7. the chlorine room location should be located in a corner of the building on the prevailing downwind side of the building and shall be away from entrances, windows, louvers, walkways, etc.,
 8. floor drains are discouraged. Where provided, the floor drains shall discharge to the outside of the building and shall not be connected to other internal or external drainage systems.
 9. where located near residential or developed areas and deemed necessary by the reviewing authority, provision shall be made to chemically neutralize chlorine gas before discharge from the water treatment plant building into the environment. Such equipment shall be designed as part of the chlorine gas storage and feed areas to automatically engage in the event of any measured chlorine release. The equipment shall be sized to treat the entire contents of the largest storage container on site.

- d. Chlorinator rooms should be heated to 60oF, and be protected from excessive heat. Cylinders and gas lines should be protected from temperatures above that of the feed equipment.
- e. Pressurized chlorine feed lines shall not carry chlorine gas beyond the chlorinator room.

5.4.2 Acids and caustics

- a. Acids and caustics shall be kept in closed corrosion-resistant shipping containers or bulk liquid storage tanks.
- b. Acids and caustics shall not be handled in open vessels, but should be pumped in undiluted form to and from bulk liquid storage tanks and covered day tanks or from shipping containers through suitable hoses, to the point of treatment.

5.4.3 Sodium chlorite for chlorine dioxide generation: Proposals for the storage and use of sodium chlorite must be approved by the reviewing authority prior to the preparation of final plans and specifications. Provisions shall be made for proper storage and handling of sodium chlorite to eliminate any danger of fire or explosion associated with its powerful oxidizing nature.

a. Storage

1. Sodium chlorite shall be stored by itself in a separate room and preferably shall be stored in an outside building detached from the water treatment facility. It shall be stored away from organic materials because many materials will catch fire and burn violently when in contact with sodium chlorite.
2. The storage structures shall be constructed of noncombustible materials.
3. If the storage structure must be located in an area where a fire may occur, water must be available to keep the sodium chlorite area cool enough to prevent heat induced explosive decomposition of the sodium chlorite.

b. Handling

1. Care should be taken to prevent spillage.
2. An emergency plan of operation should be available for the clean up of any spillage.
3. Storage drums must be thoroughly flushed to an acceptable drain prior to recycling or disposal.

c. Feeders

1. Positive displacement feeders shall be provided.
2. Tubing for conveying sodium chlorite or chlorine dioxide solutions shall be Type 1 PVC, polyethylene or materials recommended by the manufacturer.
3. Chemical feeders may be installed in chlorine rooms if sufficient space is provided or in separate rooms meeting the requirements of subsection 5.4.1.
4. Feed lines shall be installed in a manner to prevent formation of gas pockets and shall terminate at a point of positive pressure.

5. Check valves shall be provided to prevent the backflow of chlorine into the sodium chlorite line.

5.4.4 Sodium hypochlorite: Sodium hypochlorite storage and handling procedures should be arranged to minimize the slow natural decomposition process of sodium hypochlorite either by contamination or by exposure to more extreme storage conditions. In addition, feed rates should be regularly adjusted to compensate for this progressive loss in chlorine content.

a. Storage

1. Sodium hypochlorite shall be stored in the original shipping containers or in sodium hypochlorite compatible bulk liquid storage tanks.
2. Storage containers or tanks shall be located out of the sunlight in a cool area and shall be vented to the outside of the building.
3. Wherever reasonably feasible, stored sodium hypochlorite shall be pumped undiluted to the point of addition. Where dilution is unavoidable, deionized or softened water should be used.
4. Storage areas, tanks, and pipe work shall be designed to avoid the possibility of uncontrolled discharges and a sufficient amount of appropriately selected spill absorbent shall be stored on-site.
5. Reusable sodium hypochlorite storage containers shall be reserved for use with sodium hypochlorite only and shall not be rinsed out or otherwise exposed to internal contamination.

b. Feeders

1. Positive displacement pumps with sodium hypochlorite compatible materials for wetted surfaces shall be used.
2. To avoid air locking in smaller installations, small diameter suction lines shall be used with foot valves and degassing pump heads.
3. In larger installations flooded suction shall be used with pipe work arranged to ease escape of gas bubbles.
4. Calibration tubes or mass flow monitors which allow for direct physical checking of actual feed rates shall be provided.
5. Injectors shall be made removable for regular cleaning where hard water is to be treated.

5.4.5 Ammonia: Ammonia for chloramine formation may be added to water either as a water solution of ammonium sulfate, or as aqua ammonia, or as anhydrous ammonia (purified 100% ammonia in liquid or gaseous form). Special provisions required for each form of ammonia are listed below.

5.4.5.1 Ammonium sulfate: A water solution is made by addition of ammonium sulfate solid to water with agitation. The tank and dosing equipment contact surfaces should be made of corrosion resistant nonmetallic materials. Provision should be made for removal of the agitator after dissolving the solid. The tank should be fitted with an air-tight lid and vented outdoors. The

application point should be at the center of treated water flow at a location where there is high velocity movement.

5.4.5.2 Aqua ammonia (ammonium hydroxide): Aqua ammonia feed pumps and storage shall be enclosed and separated from other operating areas. The aqua ammonia room shall be equipped as in Section 5.4.1 with the following changes:

- a. Corrosion resistant, closed, unpressurized tank shall be used for bulk liquid storage and day tanks, vented through inert liquid traps to a high point outside.
- b. An incompatible connector or lockout provisions shall be provided to prevent accidental addition of other chemicals to the bulk liquid storage tank(s).
- c. The bulk liquid storage tank(s) shall be designed to avoid conditions where temperature increases cause the ammonia vapor pressure over the aqua ammonia to exceed atmospheric pressure. Such provisions shall include either:
 1. refrigeration or other means of external cooling, and/or
 2. dilution and mixing of the contents with water without opening the bulk liquid storage tank.
- d. An exhaust fan shall be installed to withdraw air from high points in the room and makeup air shall be allowed to enter at a low point.
- e. The aqua ammonia feed pump, regulators, and lines shall be fitted with pressure relief vents discharging outside the building away from any air intake and with water purge lines leading back to the headspace of the bulk storage tank.
- f. The aqua ammonia shall be conveyed direct from a day tank to the treated water stream injector without the use of a carrier water stream unless the carrier stream is softened.
- g. The application point should be placed in a region of rapid, preferably turbulent, water flow.
- h. Provisions should be made for easy access for removal of calcium scale deposits from the injector.
- i. Provision of a modestly-sized scrubber capable of handling occasional minor emissions should be considered.

5.4.5.3 Anhydrous ammonia: Anhydrous ammonia is readily available as a pure liquefied gas under moderate pressure in cylinders or as a cryogenic liquid boiling at -15 Celsius at atmospheric pressure. The liquid causes severe burns on skin contact.

- a. Anhydrous ammonia and storage feed systems (including heaters where required) shall be enclosed and separated from other works areas and constructed of corrosion resistant materials.
- b. Pressurized ammonia feed lines should be restricted to the ammonia room.

- c. An emergency air exhaust system, as in Section 5.4.1c but with an elevated intake, shall be provided in the ammonia storage room.
- d. Leak detection systems shall be provided in all areas through which ammonia is piped.
- e. Special vacuum breaker/regulator provisions must be made to avoid potentially violent results of backflow of water into cylinders or storage tanks.
- f. Carrier water systems of soft or pre-softened water may be used to transport ammonia to the application point and to assist in mixing.
- g. The ammonia injector should use a vacuum eductor or should consist of a perforated tube fitted with a closely fitting flexible rubber tubing seal punctured with a number of small slits to delay fouling by lime or other scale deposits.
- h. Provision should be made for the periodic removal of lime or other scale deposits from injectors and carrier piping.
- i. Consideration shall be given to the provision of an emergency gas scrubber capable of absorbing the entire contents of the largest anhydrous ammonia storage unit whenever there is a risk to the public as a result of potential ammonia leaks.

5.4.6 Potassium permanganate

- a. A source of heated water should be available for dissolving potassium permanganate, and
- b. mechanical mixers shall be provided.

5.4.7 Fluoride

- a. At least two diaphragm operated anti-siphon devices shall be provided on all fluoride saturator or fluosilicic acid feed systems:
 - 1. One diaphragm operated anti-siphon device shall be located on the discharge side of the feed pump, and
 - 2. A second diaphragm operated anti-siphon device shall be located at the point of application.
- b. A physical break box may be required in high hazard situations where the application point is substantially lower than the metering pump. In this situation, either a dual head feed pump or two separate pumps are required and the anti-siphon device at the discharge side of the pump may be omitted.
- c. The point of application shall:
 - 1. Enter into the lower half of the pipe, preferably at a 45 degree angle from the bottom of the pipe, and
 - 2. Shall protrude into the pipe one third of the pipe diameter.

PART 6 - PUMPING FACILITIES

6.0 GENERAL: Pumping facilities shall be designed to maintain the sanitary quality of pumped water. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pumping station shall be subject to flooding.

6.1 LOCATION: The pumping station shall be so located that the proposed site will meet the requirements for sanitary protection of water quality, hydraulics of the system and protection against interruption of service by fire, flood or any other hazard.

6.1.1 Site protection: The station shall be

- a. elevated to a minimum of three feet above the 100-year flood elevation, or three feet above the highest recorded flood elevation, whichever is higher, or protected to such elevations,
- b. readily accessible at all times unless permitted to be out of service for the period of inaccessibility,
- c. graded around the station so as to lead surface drainage away from the station,
- d. protected to prevent vandalism and entrance by animals or unauthorized persons. The pump station should be located within a secure area such as a locked building or fenced area.
- e. labeled such that the pumps and valves in the station are tagged to correspond to the maintenance record and for proper identification.

6.2 PUMPING STATIONS: Both raw and finished water pumping stations shall

- a. have adequate space for the installation of additional units if needed, and for the safe servicing of all equipment,
- b. be of durable construction, fire and weather resistant and with outward-opening doors,
- c. have floor elevation of at least six inches above finished grade,
- d. have underground structure waterproofed,
- e. have all floors drained in such a manner that the quality of the potable water will not be endangered. All floors shall slope to a suitable drain,
- f. provide a suitable outlet for drainage from pump glands without discharging onto the floor.

6.2.1 Suction well: Suction wells shall

- a. be watertight,
- b. have floors sloped to permit removal of water and settled solids,
- c. be covered or otherwise protected against contamination,
- d. have two pumping compartments or other means to allow the suction well to be taken out of service for inspection maintenance or repair.

6.2.2 Equipment servicing: Pump stations shall be provided with

- a. crane-ways, hoist beams, eyebolts, or other adequate facilities for servicing or removal of pumps, motors or other heavy equipment,
- b. openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment,
- c. a convenient tool board, or other facilities as needed, for proper maintenance of the equipment.

6.2.3 Stairways and ladders: Stairways or ladders shall

- a. be provided between all floors, and in pits or compartments which must be entered,
- b. have handrails on both sides, and treads of non-slip material. Stairs are preferred in areas where there is frequent traffic or where supplies are transported by hand. They shall have risers not exceeding nine inches and treads wide enough for safety.

6.2.4 Heating: Provisions shall be made for adequate heating for

- a. the comfort of the operator,
- b. the safe and efficient operation of the equipment.
- c. In pump houses not occupied by personnel, only enough heat need be provided to prevent freezing of equipment or treatment process.

6.2.5 Ventilation: Ventilation shall conform to existing local and/or state codes. Adequate ventilation shall be provided for all pumping stations for operator comfort and dissipation of excess heat from the equipment. Forced ventilation of at least six changes of air per hour shall be provided for

- a. all confined rooms, compartments, pits and other enclosures below ground floor,
- b. any area where unsafe atmosphere may develop or where excessive heat may be built up.

6.2.6 Dehumidification: In areas where excess moisture could cause hazards to safety or damage to equipment, means for dehumidification should be provided.

6.2.7 Lighting: Pump stations shall be adequately lighted throughout to deter vandalism and facilitate maintenance. All electrical work shall conform to the requirements of the National Electrical Code or to relevant state and/or local codes.

6.2.8 Sanitary and other conveniences: All pumping stations that are manned for extended periods should be provided with potable water, lavatory and toilet facilities. Plumbing must be so installed as to prevent contamination of a public water supply. Wastes shall be discharged in accordance with Part 9.

6.3 PUMPS: At least two pumping units shall be provided. With any pump out of service, the remaining pump or pumps shall be capable of providing the maximum pumping demand of the system. The pumping units shall

- a. have ample capacity to supply the peak demand against the required distribution system pressure without dangerous overloading,
- b. be driven by prime movers able to meet the maximum horsepower condition of the pumps,

- c. be provided with readily available spare parts and tools,
- d. be served by control equipment that has proper heater and overload protection for air temperature encountered.

6.3.1 Suction lift: Suction lift shall

- a. be avoided, if possible,
- b. be within allowable limits, preferably less than 15 feet.
- c. If suction lift is necessary, provision shall be made for priming the pumps.

6.3.2 Priming: Prime water must not be of lesser sanitary quality than that of the water being pumped. Means shall be provided to prevent either backpressure or backsiphonage backflow. When an air-operated ejector is used, the screened intake shall draw clean air from a point at least 10 feet above the ground or other source of possible contamination, unless the air is filtered by an apparatus approved by the reviewing authority. Vacuum priming may be used.

6.4 BOOSTER PUMPS: Booster pumps shall be located or controlled so that

- a. they will not produce negative pressure in their suction lines,
- b. pumps installed in the distribution system shall maintain inlet pressure as required in Section 8.2.1 under all operating conditions. Pumps taking suction from storage tanks shall be provided adequate net positive suction head,
- c. automatic shutoff or low pressure controller shall maintain at least 20 psi (140 kPa) in the suction line under all operating conditions, unless otherwise acceptable to the reviewing authority. Pumps taking suction from ground storage tanks shall be equipped with automatic shutoffs or low pressure controllers as recommended by the pump manufacturer,
- d. automatic or remote control devices shall have a range between the start and cutoff pressure which will prevent excessive cycling,
- e. a bypass is available.

6.4.1 Duplicate pumps: Each booster pumping station shall contain not less than two pumps with capacities such that peak demand can be satisfied with the largest pump out of service.

6.4.2 Metering: All booster pumping stations shall be fitted with a flow rate indicating and totalizer meter.

6.4.3 Inline booster pumps: In addition to the other requirements of this section, inline booster pumps shall be accessible for servicing and repairs.

6.4.4 Individual residential booster pumps: Private booster pumps shall not be allowed for any individual residential service from the public water supply main.

6.5 AUTOMATIC AND REMOTE CONTROLLED STATIONS: All automatic stations should be provided with automatic signaling apparatus which will report when the station is out of service. All remote controlled stations shall be electrically operated and controlled and shall have signaling apparatus of proven performance. Installation of electrical equipment shall conform with the applicable state and local electrical codes and the National Electrical Code.

6.6 APPURTENANCES

6.6.1 Valves: Each pump must have an isolation valve on the intake and discharge side of the pump to permit satisfactory operation, maintenance and repair of the equipment. If foot valves are necessary, they shall have a net valve area of at least 2 ½ times the area of the suction pipe and they shall be screened. Each pump shall have a positive-acting check valve on the discharge side between the pump and the shut-off valve. Surge relief valves or slow acting check valves shall be designed to minimize hydraulic transients.

6.6.2 Piping: In general, piping shall

- a. be designed so that the friction losses will be minimized,
- b. not be subject to contamination,
- c. have watertight joints,
- d. be protected against surge or water hammer and provided with suitable restraints where necessary,
- e. be such that each pump has an individual suction line or that the lines shall be so manifolded that they will insure similar hydraulic and operating conditions.

6.6.3 Gauges and meters: Each pump

- a. shall have a standard pressure gauge on its discharge line,
- b. shall have a compound gauge on its suction line,
- c. shall have recording gauges in the larger stations,
- d. should have a means for measuring the discharge.

The station shall have indicating, totalizing, and recording metering of the total water pumped.

6.6.4 Water seals: Water seals shall not be supplied with water of a lesser sanitary quality than that of the water being pumped. Where pumps are sealed with potable water and are pumping water of lesser sanitary quality, the seal shall

- a. be provided with either an approved reduced pressure principle backflow preventer or a break tank open to atmospheric pressure,
- b. where a break tank is provided, have an air gap of at least six inches or two pipe diameters, whichever is greater, between the feeder line and the flood rim of the tank.

6.6.5 Controls: Pumps, their prime movers and accessories, shall be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision shall be made for alternation. Provision shall be made to prevent energizing the motor in the event of a backspin cycle. Electrical controls shall be located above grade. Equipment shall be provided or other arrangements made to prevent surge pressures from activating controls which switch on pumps or activate other equipment outside the normal design cycle of operation.

6.6.6 Standby power: To ensure continuous service when the primary power has been interrupted, a power supply shall be provided from at least two independent sources or a standby or an auxiliary source shall be provided. If standby power is provided by onsite generators or engines, the fuel storage and fuel line must be designed to protect the water supply from contamination. (See Section 2.6). Carbon monoxide detectors are recommended when generators are housed within pump stations.

6.6.7 Water pre-lubrication: When automatic pre-lubrication of pump bearings is necessary and an auxiliary direct drive power supply is provided, the pre-lubrication line shall be provided with a valved bypass around the automatic control so that the bearings can, if necessary, be lubricated manually before the pump is started or the pre-lubrication controls shall be wired to the auxiliary power supply.

6.6.8 Oil or Grease Lubrication: All lubricants which come into contact with the potable water shall be certified for conformance to ANSI/NSF Standard 60.

PART 7 - FINISHED WATER SOURCE

7.0 GENERAL: The materials and designs used for finished water storage structures shall provide stability and durability as well as protect the quality of the stored water. Steel structures shall follow the current AWWA standards concerning steel tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable. Other materials of construction are acceptable when properly designed to meet the requirements of Part 7.

7.0.1 Sizing: Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands, and where fire protection is provided, fire flow demands.

- a. Fire flow requirements established by the appropriate state Insurance Services Office should be satisfied where fire protection is provided.
- b. The minimum storage capacity (or equivalent capacity) for systems not providing fire protection shall be equal to the average daily consumption. This requirement may be reduced when the source and treatment facilities have sufficient capacity with standby power to supplement peak demands of the system.
- c. Excessive storage capacity should be avoided to prevent potential water quality deterioration problems.

7.0.2 Location of reservoirs

- a. Consideration should be given to maintaining water quality when locating water storage facilities.
- b. The bottom of ground level reservoirs and standpipes should be placed at the normal ground surface and shall be above the 100 Year Flood or the highest flood of record.
- c. If the bottom elevation of a storage reservoir must be below normal ground surface, it shall be placed above the groundwater table. At least 50 per cent of the water depth should be above grade. Sewers, drains, standing water, and similar sources of possible contamination must be kept at least 50 feet from the reservoir. Gravity

sewers constructed of water main quality pipe, pressure tested in place without leakage, may be used at distances greater than 20 feet but less than 50 feet.

- d. The top of a partially buried storage structure shall not be less than two feet above normal ground surface. Clearwells constructed under filters may be excepted from this requirement when the design provides adequate protection from contamination.

7.0.3 Protection from contamination: All finished water storage structures shall have suitable watertight roofs which exclude birds, animals, insects, and excessive dust. The installation of appurtenances, such as antenna, shall be done in a manner that ensures no damage to the tank, coatings or water quality, or corrects any damage that occurred.

7.0.4 Protection from trespassers: Fencing, locks on access manholes, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage. Consideration should be given to the installation of high strength, cut resistant locks or lock covers to prevent direct cutting of a lock.

7.0.5 Drains: No drain on a water storage structure may have a direct connection to a sewer or storm drain. The design shall allow draining the storage facility for cleaning or maintenance without causing loss of pressure in the distribution system.

7.0.6 Stored Water Turnover: The system should be designed to facilitate turnover of water in the reservoir. Consideration should be given to separate inlet and outlet pipes, baffle walls or other acceptable means to avoid stagnation.

7.0.7 Overflow: All water storage structures shall be provided with an overflow which is brought down to an elevation between 12 and 24 inches above the ground surface, and discharges over a drainage inlet structure or a splash plate. No overflow may be connected directly to a sewer or a storm drain. All overflow pipes shall be located so that any discharge is visible.

- a. When an internal overflow pipe is used on elevated tanks, it should be located in the access tube. For vertical drops on other types of storage facilities, the overflow pipe should be located on the outside of the structure.
- b. The overflow for a ground-level storage reservoir shall open downward and be screened with twenty-four mesh noncorrodible screen. The screen shall be installed within the overflow pipe at a location least susceptible to damage by vandalism.
- c. The overflow for an elevated tank shall open downward and be screened with a four mesh, non-corrodible screen. The screen shall be installed within the overflow pipe at a location least susceptible to damage by vandalism.
- d. The overflow pipe shall be of sufficient diameter to permit waste of water in excess of the filling rate.
- e. In cold climates, use of a flapper should be considered to minimize air movement and hence ice formation in the tank. If a flapper valve is utilized in cold climates, provisions must be included to prevent the flapper from freezing shut. If a flapper valve is used, a screen shall be provided inside the valve.

7.0.8 Access: Finished water storage structures shall be designed with reasonably convenient access to the interior for cleaning and maintenance. At least two (2) manholes shall be provided above the waterline at each water compartment where space permits.

7.0.8.1 Elevated Storage Structures

- a. At least one of the access manholes shall be framed at least four inches above the surface of the roof at the opening. They shall be fitted with a solid water tight cover which overlaps the framed opening and extends down around the frame at least two inches, shall be hinged on one side, and shall have a locking device.
- b. All other manholes or access ways shall be bolted and gasketed according to the requirements of the reviewing authority, or shall meet the requirements of (a).

7.0.8.2 Ground Level Structures

- a. Each manhole shall be elevated at least 24 inches above the top of the tank or covering sod, whichever is higher.
- b. Each manhole shall be fitted with a solid water tight cover which overlaps a framed opening and extends down around the frame at least two inches. The frame shall be at least four inches high. Each cover shall be hinged on one side, and shall have a locking device.

7.0.9 Vents: Finished water storage structures shall be vented. The overflow pipe shall not be considered a vent. Open construction between the sidewall and roof is not permissible. Vents

- a. shall prevent the entrance of surface water and rainwater,
- b. shall exclude birds and animals,
- c. should exclude insects and dust, as much as this function can be made compatible with effective venting,
- d. shall, on ground-level structures, open downward with the opening at least 24 inches above the roof or sod and covered with twenty-four mesh non-corrodible screen. The screen shall be installed within the pipe at a location least susceptible to vandalism.
- e. shall, on elevated tanks and standpipes, open downward, and be fitted with either four mesh non-corrodible screen, or with finer mesh non-corrodible screen in combination with an automatically resetting pressure-vacuum relief mechanism, as required by the reviewing authority.

7.0.10 Roof and sidewall: The roof and sidewalls of all water storage structures must be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow. Particular attention shall be given to the sealing of roof structures which are not integral to the tank body.

- a. Any pipes running through the roof or sidewall of a metal storage structure must be welded, or properly gasketed. In concrete tanks, these pipes shall be connected to standard wall castings which were poured in place during the forming of the concrete. These wall castings should have seepage rings imbedded in the concrete.
- b. Openings in the roof of a storage structure designed to accommodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent contamination from surface or floor drainage.
- c. Valves and controls should be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir.
- d. The roof of the storage structure shall be well drained. Downspout pipes shall not enter or pass through the reservoir. Parapets, or similar construction which would tend to hold water and snow on the roof, will not be approved unless adequate waterproofing and drainage are provided.
- e. The roof of concrete reservoirs with earthen cover shall be sloped to facilitate drainage. Consideration should be given to installation of an impermeable membrane roof covering.
- f. Reservoirs with pre-cast concrete roof structures must be made watertight with the use of a waterproof membrane or similar product.

7.0.11 Construction Materials: The material used in construction of reservoirs shall be acceptable to the reviewing authority. Porous material, including wood and concrete block, are not suitable for potable water contact applications.

7.0.12 Safety: Safety must be considered in the design of the storage structure. The design shall conform to pertinent laws and regulations of the area where the water storage structure is constructed.

- a. Ladders, ladder guards, balcony railings, and safely located entrance hatches shall be provided where applicable.
- b. Elevated tanks with riser pipes over eight inches in diameter shall have protective bars over the riser openings inside the tank.
- c. Railings or handholds shall be provided on elevated tanks where persons must transfer from the access tube to the water compartment.
- d. Confined space entry requirements shall be considered.

7.0.13 Freezing: Finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents, shall be designed to prevent freezing which will interfere with proper functioning. Equipment used for freeze protection that will come into contact with the potable water shall meet ANSI/NSF Standard 61 or be approved by the reviewing authority. If a water circulation system is used, it is recommended that the circulation pipe be located separately from the riser pipe.

7.0.14 Internal catwalk: Every catwalk over finished water in a storage structure shall have a solid floor with sealed raised edges, designed to prevent contamination from shoe scrapings and dirt.

7.0.15 Silt stop: The discharge pipes from water storage structures shall be located in a manner that will prevent the flow of sediment into the distribution system. Removable silt stops should be provided.

7.0.16 Grading: The area surrounding a ground-level structure shall be graded in a manner that will prevent surface water from standing within 50 feet of it.

7.0.17 Painting and/or cathodic protection: Proper protection shall be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.

- a. Paint systems shall meet ANSI/NSF standard 61 and be acceptable to the reviewing authority. Interior paint must be applied, cured, and used in a manner consistent with the ANSI/NSF approval. After curing, the coating shall not transfer any substance to the water which will be toxic or cause taste or odor problems. Prior to placing in service, an analysis for volatile organic compounds is advisable to establish that the coating is properly cured. Consideration should be given to 100 % solids coatings.
- b. Wax coatings for the tank interior shall not be used on new tanks. Recoating with a wax system is strongly discouraged. Old wax coating must be completely removed before using another tank coating.
- c. Cathodic protection should be designed and installed by competent technical personnel, and a maintenance contract should be provided.

7.0.18 Disinfection

- a. Finished water storage structures shall be disinfected in accordance with AWWA Standard C652. Two or more successive sets of samples, taken at 24-hour intervals, shall indicate microbiologically satisfactory water before the facility is placed into operation.
- b. Disposal of heavily chlorinated water from the tank disinfection process shall be in accordance with the requirements of the state regulatory agency.
- c. The disinfection procedure specified in AWWA Standard C652 chlorination method 3, section 4.3 which allows use of the highly chlorinated water held in the storage tank for disinfection purposes, is not recommended. The chlorinated water may contain various disinfection by-products which should be kept out of the distribution system. If this procedure is used, it is recommended that the initial heavily chlorinated water be properly disposed.

7.0.19 Provisions for sampling: Smooth-nosed sampling tap(s) shall be provided to facilitate collection of water samples for both bacteriological and chemical analyses. The sample tap(s) shall be easily accessible.

7.1 TREATMENT PLANT STORAGE: The applicable design standards of Section 7.0 shall be followed for plant storage.

7.1.1 Filter washwater tanks: Filter washwater tanks shall be sized, in conjunction with available pump units and finished water storage, to provide the backwash water required by Section 4.2.1.11. Consideration must be given to the backwashing of several filters in rapid succession.

7.1.2 Clearwell: Clearwell storage should be sized, in conjunction with distribution system storage, to relieve the filters from having to follow fluctuations in water use.

- a. When finished water storage is used to provide disinfectant contact time (see Section 4.3.2) special attention must be given to tank size and baffling. (See Section 7.1.2.b below.)
- b. To ensure adequate disinfectant contact time, sizing of the clearwell should include extra volume to accommodate depletion of storage during the nighttime for intermittently operated filtration plants with automatic high service pumping from the clearwell during non-treatment hours.
- c. An overflow and vent shall be provided.
- d. A minimum of two clearwell compartments shall be provided.

7.1.3 Adjacent storage: Finished or treated water must not be stored or conveyed in a compartment adjacent to untreated or partially treated water when the two compartments are separated by a single wall, unless approved by the reviewing authority.

7.1.4 Other treatment plant storage tanks: Unless otherwise allowed by the reviewing authority, other treatment plant storage tanks/basins such as detention basins, backwash reclaim tanks, receiving basins and pump wet-wells for finished water shall be designed as finished water storage structures.

7.2 HYDROPNEUMATIC TANK SYSTEMS: Hydropneumatic (pressure) tanks, when provided as the only water storage are acceptable only in very small water systems. Systems serving more than 150 living units should have ground or elevated storage designed in accordance with Section 7.1 or 7.3. Hydropneumatic tank storage is not to be permitted for fire protection purposes. Pressure tanks shall meet ASME code requirements or an equivalent requirement of state and local laws and regulations for the construction and installation of unfired pressure vessels. Non-ASME, factory-built hydropneumatic tanks may be allowed if approved by the reviewing authority.

7.2.1 Location: The tank shall be located above normal ground surface and be completely housed.

7.2.2 System sizing

- a. The capacity of the wells and pumps in a hydropneumatic system should be at least ten times the average daily consumption rate.
- b. The gross volume of the hydropneumatic tank, in gallons, should be at least ten times the capacity of the largest pump, rated in gallons per minute. For example, a 250 gpm pump should have a 2,500 gallon pressure tank, unless other measures (e.g., variable speed drives in conjunction with the pump motors) are provided to meet the maximum demand.
- c. Sizing of hydropneumatic storage tanks must consider the need for disinfectant contact time.

7.2.3 Piping: The hydropneumatic tank(s) shall have bypass piping to permit operation of the system while the tank is being repaired or painted.

7.2.4 Appurtenances: Each tank shall have an access manhole, a drain, and control equipment consisting of a pressure gauge, water sight glass, automatic or manual air blow-off, means for adding air, and pressure operated start-stop controls for the pumps. A pressure relief valve shall be installed and be capable of handling the full pumpage rate of flow at the pressure vessel design limit. Where practical the access manhole should be 24 inches in diameter.

7.3 DISTRIBUTION SYSTEM STORAGE: The applicable design standards of Section 7.0 shall be followed for distribution system storage.

7.3.1 Pressures: The maximum variation between high and low levels in storage structures providing pressure to a distribution system should not exceed 30 feet. The minimum working pressure in the distribution system should be 35 psi (240 kPa) and the normal working pressure should be approximately 60 to 80 psi (410 - 550 kPa). When static pressures exceed 100 psi (690 kPa), pressure reducing devices shall be provided on mains or as part of the meter setting on individual service lines in the distribution system.

7.3.2 Drainage: Finished water storage structures which provide pressure directly to the distribution system shall be designed so they can be isolated from the distribution system and drained for cleaning or maintenance without causing a loss of pressure in the distribution system. The storage structure drain shall discharge to the ground surface with no direct connection to a sewer or storm drain.

7.3.3 Level controls: Adequate controls shall be provided to maintain levels in distribution system storage structures. Level indicating devices should be provided at a central location.

- a. Pumps should be controlled from tank levels with the signal transmitted by telemetering equipment when any appreciable head loss occurs in the distribution system between the source and the storage structure.
- b. Altitude valves or equivalent controls may be required for a second and subsequent structures on the system.
- c. Overflow and low-level warnings or alarms should be located where they will be under responsible surveillance 24 hours a day.

PART 8 - DISTRIBUTION SYSTEM PIPING AND APPURTENANCES

8.0 GENERAL: Water distribution systems shall be designed to maintain treated water quality. Special consideration should be given to distribution main sizing, providing for design of multidirectional flow, adequate valving for distribution system control, and provisions for adequate flushing. Systems should be designed to maximize turnover and to minimize residence times while delivering acceptable pressures and flows.

8.1 MATERIALS

8.1.1 Standards and materials selection

- a. All materials including pipe, fittings, valves and fire hydrants shall conform to the latest standards issued by the ASTM, AWWA and ANSI/NSF, where such standards exist, and be acceptable to the reviewing authority.
- b. In the absence of such standards, materials meeting applicable Product Standards and acceptable to the reviewing authority may be selected.
- c. Special attention shall be given to selecting pipe materials which will protect against both internal and external pipe corrosion.
- d. Pipes and pipe fittings containing more than 8% lead shall not be used. All products shall comply with ANSI/NSF standards.
- e. All materials used for the rehabilitation of watermains shall meet ANSI/NSF standards.

8.1.2 Permeation by organic compounds: Where distribution systems are installed in areas of groundwater contaminated by organic compounds,

- a. pipe and joint materials which do not allow permeation of the organic compounds shall be used.
- b. non-permeable materials shall be used for all portions of the system including, pipe, joint materials, hydrant leads, and service connections.

8.1.3 Used materials: Water mains which have been used previously for conveying potable water may be reused provided they meet the above standards and have been restored practically to their original condition.

8.1.4 Joints: Packing and jointing materials used in the joints of pipe shall meet the standards of AWWA and the reviewing authority. Pipe having mechanical joints or slip-on joints with rubber gaskets is preferred. Gaskets containing lead shall not be used. Repairs to lead-joint pipe shall be made using alternative methods. Manufacturer approved transition joints shall be used between dissimilar piping materials.

8.2 SYSTEM DESIGN

8.2.1 Pressure: All water mains, including those not designed to provide fire protection, shall be sized after a hydraulic analysis based on flow demands and pressure requirements. The system shall be kPa) at ground level at all points in the distribution system under all conditions of flow. The normal working pressure in the distribution system should be approximately 60 to 80 psi (410 - 550 kPa) and not less than 35 psi (240 kPa).

8.2.2 Diameter: The minimum size of water main which provides for fire protection and serving fire hydrants shall be six-inch diameter. Larger size mains will be required if necessary to allow the withdrawal of the required fire flow while maintaining the minimum residual pressure specified in [Section 8.1.1](#).

The minimum size of water main in the distribution system where fire protection is not to be provided should be a minimum of three (3) inch diameter. Any departure from minimum requirements shall be justified by hydraulic analysis and future water use, and can be considered only in special circumstances.

8.2.3 Fire protection: When fire protection is to be provided, system design should be such that fire flows and facilities are in accordance with the requirements of the State Insurance Services Office.

8.2.4 Dead ends:

- a. Dead ends shall be minimized by making appropriate tie-ins whenever practical, in order to provide increased reliability of service and reduce head loss.
- b. Dead end mains shall be equipped with a means to provide adequate flushing. Flushing devices should be sized to provide flows which will give a velocity of at least 2.5 feet per second in the water main being flushed. They may be provided with a fire hydrant if flow and pressure are sufficient. No flushing device shall be directly connected to any sewer.

8.3 VALVES: A sufficient number of valves shall be provided on water mains to minimize inconvenience and sanitary hazards during repairs. Valves should be located at not more than 500 foot intervals in commercial districts and at not more than one block or 800 foot intervals in other districts. Where systems serve widely scattered customers and where future development is not expected, the valve spacing should not exceed one mile.

8.4 HYDRANTS:

8.4.1 Location and spacing

- a. Fire hydrants should be provided at each street intersection and at intermediate points between intersections as recommended by the State Insurance Services Office. Generally, fire hydrant spacing ranges from 350 to 600 feet depending on the area being served.
- b. Water mains not designed to carry fire-flows shall not have fire hydrants connected to them. It is recommended that flushing hydrants be provided on these systems. Flushing devices should be sized to provide flows which will give a velocity of at least 2.5 feet per second in the water main being flushed. No flushing device shall be directly connected to any sewer.

8.4.2 Valves and nozzles: Fire hydrants should have a bottom valve size of at least five inches, one 4-1/2 inch pumper nozzle and two 2-1/2 inch nozzles.

8.4.3 Hydrant leads: The hydrant lead shall be a minimum of six inches in diameter. Auxiliary valves shall be installed on all hydrant leads.

8.4.4 Hydrant drainage

- a. Hydrant drains should be plugged. When the drains are plugged the barrels must be pumped dry after use during freezing weather.
- b. Where hydrant drains are not plugged, a gravel pocket or dry well shall be provided unless the natural soils will provide adequate drainage.
- c. Hydrant drains shall not be connected to or located within 10 feet of sanitary sewers, storm sewers, or storm drains.
- d. Hydrant drains, where allowed, must be above the seasonal groundwater table.

8.5 AIR RELIEF VALVES

8.5.1 Air relief valves: At high points in water mains where air can accumulate provisions shall be made to remove the air by means of air relief valves. Automatic air relief valves shall not be used in situations where flooding of the manhole or chamber may occur.

8.5.2 Air relief valve piping

- a. Use of manual air relief valves is recommended wherever possible.
- b. The open end of an air relief pipe from a manually operated valve should be extended to the top of the pit and provided with a screened, downward-facing elbow if drainage is provided for the manhole.
- c. The open end of an air relief pipe from automatic valves shall be extended to at least one foot above grade and provided with a screened, downward-facing elbow.
- d. Discharge piping from air relief valves shall not connect directly to any storm drain, storm sewer, or sanitary sewer.

8.6 VALVE, METER AND BLOW-OFF CHAMBERS: Wherever possible, chambers, pits or manholes containing valves, blow-offs, meters, or other such appurtenances to a distribution system, shall not be located in areas subject to flooding or in areas of high groundwater. Such chambers or pits should drain to the ground surface, or to absorption pits underground. The chambers, pits and manholes shall not connect directly to any storm drain or sanitary sewer. Blow-offs shall not connect directly to any storm drain or sanitary sewer.

8.7 INSTALLATION OF WATER MAINS

8.7.1 Standards: Specifications shall incorporate the provisions of the AWWA standards and/or manufacturer's recommended installation procedures.

8.7.2 Bedding: A continuous and uniform bedding shall be provided in the trench for all buried pipe. Backfill material shall be tamped in layers around the pipe and to a sufficient height above the pipe to adequately support and protect the pipe. Stones found in the trench shall be removed for a depth of at least six inches below the bottom of the pipe.

8.7.3 Cover: Water mains shall be covered with sufficient earth or other insulation to prevent freezing.

8.7.4 Blocking: All tees, bends, plugs and hydrants shall be provided with reaction blocking, tie rods or joints designed to prevent movement.

8.7.5 Anchoring of fusible pipe: Additional restraint may be necessary on fusible pipe at the connection to appurtenances or transitions to different pipe materials to prevent separation of joints. The restraint may be provided in the form of an anchor ring encased in concrete or other methods as approved by the reviewing authority.

8.7.6 Pressure and leakage testing: Installed pipe shall be pressure tested and leakage tested in accordance with the appropriate AWWA Standards.

8.7.7 Disinfection: New, cleaned and repaired water mains shall be disinfected in accordance with AWWA Standard C651. The specifications shall include detailed procedures for the adequate flushing, disinfection, and microbiological testing of all water mains. In an emergency or unusual situation, the disinfection procedure shall be discussed with the reviewing authority.

8.7.8 External corrosion: If soils are found to be aggressive, take necessary action to protect the water main, such as by encasement of the water main in polyethylene, provision of cathodic protection (in very severe instances), or using corrosion resistant water main materials.

8.8 SEPARATION DISTANCES FROM CONTAMINATION SOURCES

8.8.1 General: The following factors should be considered in providing adequate separation:

- a. materials and type of joints for water and sewer pipes,
- b. soil conditions,
- c. service and branch connections into the water main and sewer line,
- d. compensating variations in the horizontal and vertical separations,
- e. space for repair and alterations of water and sewer pipes,
- f. off-setting of pipes around manholes.

8.8.2 Parallel installation

- a. Water mains shall be laid at least 10 feet horizontally from any existing or proposed gravity sanitary or storm sewer, septic tank, or subsoil treatment system. The distance shall be measured edge to edge.
- b. In cases where it is not practical to maintain a 10 foot separation, the reviewing authority may allow deviation on a case-by-case basis, if supported by data from the design engineer.

8.8.3 Crossings

- a. Water mains crossing sewers shall be laid to provide a minimum vertical distance of 18 inches between the outside of the water main and the outside of the sewer. This shall be the case where the water main is either above or below the sewer with preference to the water main located above the sewer.
- b. At crossings, one full length of water pipe shall be located so both joints will be as far from the sewer as possible. Special structural support for the water and sewer pipes may be required.

8.8.4 Exception: When it is impossible to obtain the minimum specified separation distances, the reviewing authority must specifically approve any variance from the requirements of Sections 8.8.2 and 8.8.3. Where sewers are being installed and Section 8.8.2 and 8.8.3 cannot be met, the following methods of installation may be used:

- a. Such deviation may allow installation of the water main closer to a sewer, provided that the water main is laid in a separate trench or on an undisturbed earth shelf located on one side of the sewer at such an elevation that the bottom of the water main is at least 18 inches above the top of the gravity sewer.
- b. the sewer materials shall be water works grade 150 psi (1.0 Mpa) pressure rated pipe meeting AWWA standards or pipe approved by the reviewing authority and shall be pressure tested to ensure water tightness.

8.8.5 Force mains: There shall be at least a 10 foot horizontal separation between water mains and sanitary sewer force mains. There shall be an 18 inch vertical separation at crossings as required in [Section 8.8.3](#).

8.8.6 Sewer manholes: No water pipe shall pass through or come in contact with any part of a sewer manhole. Water main should be located at least 10 feet from sewer manholes.

8.8.7 Separation of water mains from other sources of contamination: Design engineers should exercise caution when locating water mains at or near certain sites such as sewage treatment plants or industrial complexes. On site waste disposal facility including absorption field must be located and avoided. The engineer must contact the reviewing authority to establish specific design requirements for locating water mains near any source of contamination.

8.9 SURFACE WATER CROSSINGS: Surface water crossings, whether over or under water, present special problems. The reviewing authority should be consulted before final plans are prepared.

8.9.1 Above-water crossings: The pipe shall be adequately supported and anchored, protected from vandalism, damage and freezing, and accessible for repair or replacement.

8.9.2 Underwater crossings: A minimum cover of five feet shall be provided over the pipe unless otherwise approved by the reviewing authority. When crossing water courses which are greater than 15 feet in width, the following shall be provided:

- a. the pipe shall be of special construction, having flexible, restrained or welded watertight joints,
- b. valves shall be provided at both ends of water crossings so that the section can be isolated for testing or repair; the valves shall be easily accessible, and not subject to flooding,
- c. permanent taps or other provisions to allow insertion of a small meter to determine leakage and obtain water samples on each side of the valve closest to the supply source.

8.10 CROSS-CONNECTIONS AND INTERCONNECTIONS

8.10.1 Cross-connections: There shall be no connection between the distribution system and any pipes, pumps, hydrants, or tanks whereby unsafe water or other contaminating materials may be discharged or drawn into the system. Each water utility shall have a program conforming to state requirements to detect and eliminate cross connections.

8.10.2 Cooling water: Neither steam condensate, cooling water from engine jackets, nor water used in conjunction with heat exchange devices shall be returned to the potable water supply.

8.10.3 Interconnections: The approval of the reviewing authority shall be obtained for interconnections between potable water supplies. Consideration should be given to differences in water quality.

8.11 WATER SERVICES AND PLUMBING

8.11.1 Plumbing: Water services and plumbing shall conform to the applicable local and/or state plumbing codes. Solders and flux containing more than 0.2% lead and pipe and pipe fittings containing more than 8% lead shall not be used.

8.11.2 Booster pumps: Individual booster pumps shall not be allowed for any individual residential service from the public water supply mains. Where permitted for other types of services, booster pumps shall be designed in accordance with Section 6.4.

8.12 SERVICE METERS: Each service connection should be individually metered.

8.13 WATER LOADING STATIONS: Water loading stations present special problems since the fill line may be used for filling both potable water vessels and other tanks or contaminated vessels. To prevent contamination of both the public supply and potable water vessels being filled, the following principles shall be met in the design of water loading stations:

- a. there shall be no backflow to the public water supply,
- b. the piping arrangement shall prevent contaminant being transferred from a hauling vessel to others subsequently using the station,
- c. hoses shall not be contaminated by contact with the ground.

PART 9 - WASTE RESIDUALS

9.0 GENERAL: All waste discharges shall be governed by regulatory agency requirements. The requirements outlined herein must, therefore, be considered minimum requirements as state water pollution control authorities may have more stringent requirements. Provisions must be made for proper disposal of water treatment plant waste such as sanitary, laboratory, clarification sludge, softening sludge, iron sludge, filter backwash water, and brines. In locating waste disposal facilities, due consideration shall be given to preventing potential contamination of the water supply. Alternative methods of water treatment and chemical use should be considered as a means of reducing waste volumes and the associated handling and disposal problems. Appropriate backflow protection must be provided on waste discharge piping as needed to protect the public water supply.

9.1 SANITARY WASTE: The sanitary waste from water treatment plants, pumping stations, and other waterworks installations must receive treatment. Waste from these facilities shall be discharged directly to a sanitary sewer system, when available and feasible, or to an adequate on-site waste treatment facility approved by the appropriate reviewing authority.

9.2 BRINE WASTE: Waste from ion exchange plants, demineralization plants, or other plants which produce a brine, may be disposed of by controlled discharge to a stream if adequate dilution is available. Surface water quality requirements of the regulatory agency will control the rate of discharge. Except when discharging to large waterways, a holding tank of sufficient size should be provided to allow the brine to be discharged over a twenty-four hour period. Where

discharging to a sanitary sewer, a holding tank may be required to prevent the overloading of the sewer and/or interference with the waste treatment processes. The effect of brine discharge to sewage lagoons may depend on the rate of evaporation from the lagoons.

9.3 PRECIPITATIVE SOFTENING SLUDGE: Sludge from plants using precipitative softening varies in quantity and in chemical characteristics depending on the softening process and the chemical characteristics of the water being softened. Recent studies show that the quantity of sludge produced is much larger than indicated by stoichiometric calculations. Methods of treatment and disposal are as follows:

a. Lagoons

1. Temporary storage lagoons which must be cleaned periodically should be designed on the basis of 0.7 acres per million gallons per day per 100 mg/L of hardness removed based on a usable lagoon depth of five feet. This should provide about 2 1/2 years storage. At least two but preferably more lagoons must be provided in order to give flexibility in operation. An acceptable means of final sludge disposal must be provided. Provisions must be made for convenient cleaning.
2. Permanent lagoons should have a volume of at least four times that for temporary lagoons.
3. The design of both temporary lagoons and permanent lagoons should provide for
 - a. location free from flooding,
 - b. when necessary, dikes, deflecting gutters or other means of diverting surface water so that it does not flow into the lagoons,
 - c. a minimum usable depth of five feet,
 - d. adequate freeboard of at least two feet,
 - e. adjustable decanting device,
 - f. effluent sampling point,
 - g. adequate safety provisions,
 - h. parallel operation, and
 - i. subsurface infiltration may be acceptable if approved by the reviewing authority.
- b. The application of liquid lime or dewatered sludge to farm land should be considered as a method of ultimate disposal. Prior to land application, a chemical analysis of the sludge including calcium and heavy metals shall be conducted. Approval from the appropriate reviewing authority shall be obtained. When this method is selected, the following provisions shall be made:
 - a. Transport of sludge by vehicle or pipeline shall incorporate a plan or design which prevents spillage or leakage during transport.
 - b. Interim storage areas at the application site shall be kept to a minimum and facilities shall be provided to prevent washoff of sludge or flooding.
 - c. Sludge shall not be applied at times when washoff of sludge from the land could be expected.

- d. Sludge shall not be applied to sloping land where washoff could be expected unless provisions are made, for suitable land, to immediately incorporate the sludge into the soil.
- e. Trace metals loading shall be limited to prevent significant increases in trace metals in the food chain, phytotoxicity or water pollution.
- f. Each area of land to receive lime sludge shall be considered individually and a determination made as to the amount of sludge needed to raise soil pH to the optimum for the crop to be grown.
- c. Discharge of lime sludge to sanitary sewers should be avoided since it may cause both liquid volume and sludge volume problems at the sewage treatment plant. This method should be used only when the sewerage system has the capability to adequately handle the lime sludge.
- d. Mixing of lime sludge with activated sludge waste may be considered as a means of co-disposal.
- e. Disposal at a landfill can be done as either a solid or liquid if the landfill can accept such waste, depending on individual state requirements.
- f. Mechanical dewatering of sludge may be considered. Pilot studies on a particular plant waste are required. Mechanical dewatering shall be preceded by sludge concentration and chemical pre-treatment.
- g. Calcination of sludge may be considered. Pilot studies on a particular plant waste are required. h. Lime sludge drying beds are not recommended.

9.4 ALUM SLUDGE: Lagooning may be used as a method of handling alum sludge. Lagoon size can be calculated using total chemicals used plus a factor for turbidity. Mechanical concentration may be considered. A pilot plant study is required before the design of a mechanical dewatering installation. Freezing changes the nature of alum sludge so that it can be used for fill. Acid treatment of sludge for alum recovery may be a possible alternative. Alum sludge can be discharged to a sanitary sewer. However, initiation of this practice will depend on obtaining approval from the owner of the sewerage system as well as from the regulatory agency before final designs are made.

9.4.1 Lagoons: Lagoons should be designed to produce an effluent satisfactory to the regulatory agency and should provide for:

- a. location free from flooding,
- b. where necessary, dikes, deflecting gutters or other means of diverting surface water so that it does not flow into the lagoon,
- c. a minimum usable depth of five feet,
- d. adequate freeboard of at least two feet,
- e. adjustable decanting device,
- f. effluent sampling point,
- g. adequate safety provisions, and

- h. a minimum of two cells, each with appropriate inlet/outlet structures to facilitate independent filling/dewatering operations.

9.4.2 Mechanical dewatering

- a. The successful use of mechanical dewatering depends on the characteristics of the alum sludge produced, as determined by site specific studies.
- b. Mechanical dewatering shall be preceded by sludge concentration and chemical pre-treatment.

9.4.3 Land application: Alum sludge may be disposed of by land application either alone, or in combination with other wastes where an agronomic value has been determined and disposal has been approved by the reviewing authority.

9.5 "RED WATER" WASTE: Waste filter wash water from iron and manganese removal plants can be disposed of as follows:

9.5.1 Sand filters: Sand filters should have the following features:

- a. Total filter area shall be sufficient to adequately dewater applied solids. Unless the filter is small enough to be cleaned and returned to service in one day, two or more cells are required.
- b. The "red water" filter shall have sufficient capacity to contain, above the level of the sand, the entire volume of wash water produced by washing all of the production filters in the plant, unless the production filters are washed on a rotating schedule and the flow through the production filters is regulated by true rate of flow controllers. Then sufficient volume shall be provided to properly dispose of the wash water involved.
- c. Sufficient filter surface area should be provided so that, during any one filtration cycle, no more than two feet of backwash water will accumulate over the sand surface.
- d. The filter shall not be subject to flooding by surface runoff or flood waters. Finished grade elevation shall be established to facilitate maintenance, cleaning and removal of surface sand as required. Flash boards or other non-watertight devices shall not be used in the construction of filter side walls.
- e. The filter media should consist of a minimum of twelve inches of sand, three to four inches of supporting small gravel or torpedo sand, and nine inches of gravel in graded layers. All sand and gravel should be washed to remove fines.
- f. Filter sand should have an effective size of 0.3 to 0.5 mm and a uniformity coefficient not to exceed 3.5. The use of larger sized sands shall be justified by the designing engineer to the satisfaction of the reviewing authority.
- g. The filter should be provided with an adequate under-drainage collection system to permit satisfactory discharge of filtrate.
- h. Provision shall be made for the sampling of the filter effluent.
- i. Overflow devices from "red water" filters shall not be permitted.

- j. Where freezing is a problem, provisions should be made for covering the filters during the winter months.
- k. "Red water" filters shall comply with the common wall provisions contained in Sections 7.1.3 and 8.10.1, which pertain to the possibility of contaminating treated water with an unsafe water.

The reviewing authority must be contacted for approval of any arrangement where a separate structure is not provided.

9.5.2 Lagoons: Lagoons shall have the following features:

- a. be designed with a volume 10 times the total quantity of wash water discharged during any 24-hour period,
- b. a minimum usable depth of three feet,
- c. length four times width, and the width at least three times the depth, as measured at the operating water level,
- d. outlet to be at the end opposite the inlet,
- e. a weir overflow device at the outlet end with weir length equal to or greater than depth,
- f. velocity to be dissipated at the inlet end.
- g. subsurface infiltration lagoons may be acceptable if approved by the reviewing authority.

9.5.3 Discharge to community sanitary sewer: Red water can be discharged to a community sewer. However, approval of this method will depend on obtaining approval from the owner of the sewerage system as well as from the regulatory agency before final designs are made. A holding tank is recommended to prevent overloading the sewers. Design shall prevent cross connections and there shall be no common walls between potable and non-potable water.

9.5.4 Discharge to surface water: Plant must have an NPDES (National Pollutant Discharge Elimination System) permit or other applicable discharge permit to dispose of backwash water into surface water.

9.5.5 Recycling "red water" wastes: Recycling of supernatant or filtrate from "red water" waste treatment facilities to the head end of an iron removal plant shall not be allowed except as approved by the reviewing authority.

9.6 WASTE FILTER WASH WATER: Disposal of backwash water from surface water treatment and lime softening plants should have suspended solids reduced to a level acceptable to the regulatory agency before being discharged to a holding tank and/or recycled to the inlet end of the plant.

1. The holding tank must be constructed in the following manner:

- a. Shall contain the anticipated volume of waste water produced by the plant when operating at design capacity.

POLICY STATEMENT ON PRE-ENGINEERED WATER TREATMENT PLANTS

Pre-engineered water treatment plants are becoming available and being used for production of potable water at public water systems. Many applications being proposed are for small systems having relatively clean surface water sources which are now being required to provide filtration under the federal Safe Drinking Water Act.

Pre-engineered water treatment plants are normally modular process units which are pre-designed for specific process applications and flow rates and purchased as a package. Multiple units may be installed in parallel to accommodate larger flows. Pre-engineered treatment plants have numerous applications but are especially applicable at small systems where conventional treatment may not be cost effective. As with any design the proposed treatment must fit the situation and assure a continuous supply of safe drinking water for water consumers. The reviewing authority may accept proposals for pre-engineered water treatment plants on a case-by-case basis where they have been demonstrated to be effective in treating the source water being used. In most cases an applicant will be required to demonstrate, through pilot studies and/or other data, adequacy of the proposed plant for the specific application. A professional engineer is required to prepare plans and specifications for submittal to the reviewing authority for approval. It is recommended that a professional engineer be on site to oversee the installation and initial startup of pre-engineered water treatment plants.

Factors to be considered include:

1. Raw water quality characteristics under normal and worst case conditions. Seasonal fluctuations must be evaluated and considered in the design.
2. Demonstration of treatment effectiveness under all raw water conditions and system flow demands. This demonstration may be on-site pilot or full scale testing or testing off-site where the source water is of similar quality. On-site testing is required at sites having questionable water quality or applicability of the treatment process. The proposed demonstration project must be approved by the reviewing authority prior to starting.
3. Sophistication of equipment. The reliability and experience record of the proposed treatment equipment and controls must be evaluated.
4. Unit process flexibility which allows for optimization of treatment.
5. Operational oversight that is necessary. At surface water sources full-time operators are necessary, except where the reviewing authority has approved an automation plan.
6. Third party certification or approvals such as National Sanitation Foundation (NSF), International Underwriters Laboratory (UL) or other acceptable ANSI accredited third parties for; a) treatment equipment and b) materials that will be in contact with the water.
7. Suitable pretreatment based on raw water quality and the pilot study or other demonstration of treatment effectiveness. Pretreatment may be included as an integral process in the pre-engineered module.
8. Factory testing of controls and process equipment prior to shipment.
9. Automated troubleshooting capability built into the control system.

10. Start-up and follow-up training and troubleshooting to be provided by the manufacturer or contractor.
11. Operation and maintenance manual. This manual must provide a description of the treatment, control and pumping equipment, necessary maintenance and schedule, and a troubleshooting guide for typical problems.
12. In addition to any automation, full manual override capabilities must be provided.
13. Cross-connection control including, but not limited to the avoidance of single wall separations between treated and partially or untreated surface water.
14. On-site and contractual laboratory capability. The on-site testing must include all required continuous and daily testing as specified by the reviewing authority. Contract testing may be considered for other parameters.
15. Manufacturer's warranty and replacement guarantee. Appropriate safeguards for the water supplier must be included in contract documents. The reviewing authority may consider interim or conditional project approvals for innovative technology where there is sufficient demonstration of treatment effectiveness and contract provisions to protect the water supplier should the treatment not perform as claimed.
16. Water supplier revenue and budget for continuing operations, maintenance and equipment replacement in the future.
17. Life expectancy and long-term performance of the units based on the corrosivity of the raw and treated water and the treatment chemicals used. Additional information on this topic is given in the State Alternative Technology Approval Protocol dated June 1996, which was developed by the Association of State Drinking Water Administrators, U.S. Environmental Protection Agency and various industry groups.

POLICY STATEMENT ON AUTOMATED/UNATTENDED OPERATION OF SURFACE WATER TREATMENT PLANTS

Recent advances in computer technology, equipment controls and Supervisory Control and Data Acquisition (SCADA) Systems have brought automated and off-site operation of surface water treatment plants into the realm of feasibility. Coincidentally, this comes at a time when renewed concern for microbiological contamination is driving optimization of surface water treatment plant facilities and operations and finished water treatment goals are being lowered to levels of <0.1 NTU turbidity and <20 total particle counts per milliliter. Review authorities encourage any measures, including automation, which assist operators in improving plant operations and surveillance functions. Automation of surface water treatment facilities to allow unattended operation and off-site control presents a number of management and technological challenges which must be overcome before an approval can be considered. Each facet of the plant facilities and operations must be fully evaluated to determine what on-line monitoring is appropriate, what alarm capabilities must be incorporated into the design and what staffing is necessary. Consideration must be given to the consequences and operational response to treatment challenges, equipment failure and loss of communications or power. An engineering report shall be developed as the first step in the process leading to design of the automation system. The engineering report to be submitted to review authorities must cover all aspects of the treatment plant and automation system including the following information/criteria:

1. Identify all critical features in the pumping and treatment facilities that will be electronically monitored, have alarms and can be operated automatically or off-site via the control system. Include a description of automatic plant shut-down controls with alarms and conditions which would trigger shut-downs. Dual or secondary alarms may be necessary for certain critical functions.
2. Automated monitoring of all critical functions with major and minor alarm features must be provided. Automated plant shutdown is required on all major alarms. Automated startup of the plant is prohibited after shutdown due to a major alarm. The control system must have response and adjustment capability on all minor alarms. Built-in control system challenge test capability must be provided to verify operational status of major and minor alarms.
3. The plant control system must have the capability for manual operation of all treatment plant equipment and process functions.
4. A plant flow diagram which shows the location of all critical features, alarms and automated controls to be provided.
5. Description of off-site control station(s) that allow observation of plant operations, receiving alarms and having the ability to adjust and control operation of equipment and the treatment process.
6. A certified operator must be on "standby duty" status at all times with remote operational capability and located within a reasonable response time of the treatment plant.
7. A certified operator must do an on-site check at least once per day to verify proper operation and plant security.
8. Description of operator staffing and training planned or completed in both process control and the automation system.
9. Operations manual which gives operators step by step procedures for understanding and using the automated control system under all water quality conditions. Emergency operations during power or communications failures or other emergencies must be included.
10. A plan for a 6 month or more demonstration period to prove the reliability of procedures, equipment and surveillance system. A certified operator must be on-duty during the demonstration period. The final plan must identify and address any problems and alarms that occurred during the demonstration period. Challenge testing of each critical component of the overall system must be included as part of the demonstration project.
11. Schedule for maintenance of equipment and critical parts replacement.
12. Sufficient finished water storage shall be provided to meet system demands and CT requirements whenever normal treatment production is interrupted as the result of automation system failure or plant shutdown.
13. Sufficient staffing must be provided to carry out daily on-site evaluations, operational functions and needed maintenance and calibration of all critical treatment components and monitoring equipment to ensure reliability of operations.
14. Plant staff must perform as a minimum weekly checks on the communication and control system to ensure reliability of operations. Challenge testing of such equipment should be part of normal maintenance routines.

15. Provisions must be made to ensure security of the treatment facilities at all times. Incorporation of appropriate intrusion alarms must be provided which are effectively communicated to the operator in charge.

POLICY STATEMENT ON BAG AND CARTRIDGE FILTERS FOR PUBLIC WATER SUPPLIES

Bag and cartridge technology has been used for some time in the food, pharmaceutical and industrial applications. This technology is increasingly being used by small public water supplies for treatment of drinking water. A number of states have accepted bag and cartridge technology as an alternate technology for compliance with the filtration requirements of the Surface Water Treatment Rule and the Long Term 1 Enhanced Surface Water Treatment Rule. In addition, bag and cartridge filters are included in the microbial toolbox options for meeting the *Cryptosporidium* treatment requirements of the Long Term 2 Enhance

Surface Water Treatment Rule.

The particulate loading capacity of these filters is low, and once expended the bag or cartridge filter must be discarded. This technology is designed to meet the low flow requirement needs of small systems. The operational and maintenance cost of bag and cartridge replacement must be considered when designing a system. These filters can effectively remove particles from water in the size range of *Giardia* cysts (5-10 microns) and *Cryptosporidium* (2-5 microns). At the present time, filtration evaluation is based on *Cryptosporidium* oocyst removal. With this type of treatment there is no alteration of water chemistry. So, once the technology has demonstrated the required removal efficiency, no further pilot demonstration may be necessary. The demonstration of filtration is specific to a specific housing and a specific bag or cartridge filter. Any other combinations of different bags, cartridges, or housings will require additional demonstration of filter efficiency. Treatment of a surface water should include source water protection, filtration, and disinfection. The following items should be considered in evaluating the applicability of bag or cartridge filtration.

Pre-design/Design

1. The filter housing and bag/cartridge filter must demonstrate a filter efficiency of at least 2-log reduction in particles size 2 micron and above. Demonstration of higher log removals may be required by the reviewing authority depending on raw water quality and other treatment steps to be employed. The reviewing authority will decide whether or not a pilot demonstration is necessary for each installation. This filtration efficiency demonstration may be accomplished by:
 - a. Microscopic particulate analysis, including particle counting, sizing and identification, which determines occurrence and removals of micro-organisms and other particles across a filter or system under ambient raw water source condition, or when artificially challenged.
 - b. *Cryptosporidium* particle removal evaluation in accordance with procedures specified in NSF Standard 53 or equivalent. These evaluations must be conducted by NSF or by another third-party whose certification would be acceptable to the reviewing authority.
 - c. "Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants" procedure specified by the EPA/NSF Environmental Technology Verification Program.
 - d. Challenge testing procedure for bag and cartridge filters presented in Chapter 8 of the Long Term 2 Enhanced Surface Water Treatment Rule Toolbox Guidance Manual.

- e. "Nonconsensus" live *Cryptosporidium* challenge studies that have been designed and carried out by a third-party agent recognized and accepted by the reviewing authority for interim evaluations. At the present time uniform protocol procedures for live *Cryptosporidium* challenge studies have not been established.
- f. Methods other than these that are approved by the reviewing authority.
2. System components such as housing, bags, cartridges, membranes, gaskets, and O-rings should be evaluated under NSF Standard 61 or equivalent, for leaching of contaminants. Additional testing may be required by the reviewing authority.
 3. The source water or pre-treated water should have a turbidity less than 3 NTU.
 4. The flow rate through the treatment process shall be monitored with a flow valve and meter. The flow rate through the bag/cartridge filter must not exceed the maximum flow rate verified by filtration efficiency testing.
 5. Pretreatment is strongly recommended (if not required by the reviewing authority). This is to provide a more constant water quality to the bag/cartridge filter and to extend bag and cartridge life. Examples of pretreatment include media filters, larger opening bag/cartridge filters, infiltration galleries, and beach wells. Location of the water intake should be considered in the pretreatment evaluation.
 6. Particle count analysis can be used to determine what level of pretreatment should be provided. It should be noted that particulate counting is a 'snap shot' in time and that there can be seasonal variations such as algae blooms, lake turnover, spring runoff, and heavy rainfall events that will give varied water quality.
 7. It is recommended that chlorine or another disinfectant be added at the head of the treatment process to reduce/eliminate the growth of algae, bacteria, etc., on the filters. The impact on disinfection-by-product formation should be considered.
 8. A filter to waste component is strongly recommended (if not required by the reviewing authority), for any pretreatment pressure sand filters. At the beginning of each filter cycle and/or after every backwash of the prefilters a set amount of water should be discharged to waste before water flows into the bag/cartridge filter. Filter to waste shall be provided for the final filter (s) and a set amount of water shall be discharged to waste after changing the filters.
 9. If pressure media filters are used for pretreatment they must be designed according to Section 4.2.2.
 10. A sampling tap shall be provided ahead of any treatment so a source water sample can be collected.
 11. Pressure gages and sampling taps shall be installed before and after the media filter and before and after the bag/cartridge filter.
 12. An automatic air release valve shall be installed on top of the filter housing.
 13. Frequent start and stop operation of the bag or cartridge filter should be avoided. To avoid this frequent start and stop cycle the following options are recommended:
 - a. a slow opening and closing valve ahead of the filter to reduce flow surges.
 - b. reduce the flow through bag or cartridge filter to as low as possible to lengthen filter run times.

c. install a recirculating pump that pumps treated water back to a point ahead of the bag or cartridge filter. Care must be taken to make sure there is no cross connection between the finished water and raw water.

14. A minimum of two bag or cartridge filter housings should be provided for water systems that must provide water continuously.

15. A pressure relief valve should be incorporated into the bag or cartridge filter housing.

16. Complete automation of the treatment system is not required. Automation of the treatment plant should be incorporated into the ability of the water system to monitor the finished water quality. It is important that a qualified water operator is available to run the treatment plant.

17. A plan of action should be in place should the water quality parameters fail to meet EPA or the local reviewing authorities standards.

Operations

1. The filtration and backwash rates shall be monitored so that the prefilters are being optimally used.

2. The bag and cartridge filters must be replaced when a pressure difference of 30 psi or other pressure difference recommended by the manufacturer or the reviewing authority is observed. It should be noted that bag filters do not load linearly. Additional observation of the filter performance is required near the end of the filter run.

3. Maintenance (o-ring replacement) shall be performed in accordance with the manufacturers recommendations.

4. Sterile rubber gloves and a disposable face mask covering the nose and mouth should be worn when replacing or cleaning the cartridge or bag filters.

5. The filter system shall be properly disinfected and water shall be ran to waste each time the cartridge or bag filter vessels are opened for maintenance.

6. The following parameters should be monitored:

Flow rate, instantaneous

Flow rate, total

Operating pressure

Pressure differential

Turbidity

POLICY STATEMENT ON ULTRA VIOLET LIGHT FOR TREATMENT OF PUBLIC WATER SUPPLIES

The United States Environmental Protection Agency (EPA) has promulgated the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) to further reduce microbial contamination of drinking water. The rule requires additional treatment for some public water supplies based on their source water *Cryptosporidium* concentrations and current treatment practices. Ultraviolet Light (UV) disinfection is one option public water supplies have to comply with the additional treatment requirements.

The EPA has released a document entitled **ULTRAVIOLET DISINFECTION GUIDANCE MANUAL FOR THE FINAL LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE**. This guidance manual will be used as the basis for the validation, design, and operation of all UV systems used for public water systems and for the development of the recommended standards for those systems. UV disinfection may also be considered as primary disinfection for public water systems with microbiologically safe ground water and must meet the same requirements as UV systems used to meet LT2ESWTR. The reviewing authority shall be contacted regarding use of UV treatment. Supplemental disinfection for additional virus inactivation or to provide a residual in the water distribution system may be required by the reviewing authority. When UV light treatment devices are used for non-health related purposes the UV device may provide doses less than indicated in the following criteria.

A. CRITERIA FOR UV WATER TREATMENT DEVICES

1. UV water treatment devices must be validated by a third-party entity in accordance with the USEPA Ultraviolet Light Disinfection Guidance Manual (USEPA UVDGM), the German Association for Gas and Water (UVGW), the Austrian Standards Institute (ONORM), the National Water Research Institute/ American Water Works Association Research Foundation (NWRI/AwwaRF), the Class A criteria under ANSI/NSF Standard 55 - Ultraviolet Microbiological Water Treatment Systems; or other standards acceptable to the reviewing authority. The validation must demonstrate that the unit is capable of providing a UV light dose of 40 millijoules per square centimeter (mJ/cm²). In addition to the requirements cited in the USEPA UVDGM each UV water treatment device shall meet the following;

a. The UV assemblies shall be accessible for visual observation, cleaning and replacement of the lamp, lamp jackets and sensor window/lens. A wiper assembly or chemical cleaning-in-place system may be installed to allow in-situ cleaning of lamp jackets. Adequate controls shall be in place to prevent contamination of the potable water with cleaning chemicals;

b. An automatic shutdown valve shall be installed in the water supply line ahead of the UV treatment system that will be activated whenever the water treatment system loses power or is tripped by a monitoring device when the dosage is below the validated operating design dose. When power is not being supplied to the UV unit the valve shall be in a closed (fail-safe) position.

c. The UV housing shall be stainless steel 304 or 316L;

2. A flow or time delay mechanism wired in series with the well or service pump shall be provided to permit a sufficient

time for lamp warm-up per manufacturer recommendations before water flows from the unit upon startup. Where there are

extended no-flow periods and fixtures are located a short distance downstream of the UV unit, consideration should be

given to UV unit shutdown between operating cycles to prevent heat build-up in the water due to the UV lamp:

3. A sufficient number (required number plus one) of parallel UV treatment systems shall be provided to assure a continuous water supply when one unit is out of service unless other satisfactory disinfection can be provided when the unit is out of service;

4. No bypasses shall be installed;

5. All water from the well shall be treated. The well owner may request a variance to treat only that portion of the water supply that is used for potable purposes provided that the daily average and peak water use is determined and signs are posted at all non-potable water supply outlets.

6. The well or booster pump(s) shall have adequate pressure capability to maintain minimum water system pressure after the water treatment devices;

B. PRETREATMENT

The reviewing authority will determine pre and post treatment on a specific case basis depending on raw water quality. See Section G for raw water quality limitations. If coliform bacteria or other microbiological organisms are present in the untreated water appropriate filtration shall be provided as minimum pretreatment. A 5 um sediment filter or equivalent is recommended for all UV installations.

C. ONLINE MONITORING, REPLACEMENT PARTS

UV light intensity of each installed unit shall be monitored continuously. Treatment units and the water system shall automatically shutdown if the UV dosage falls below the validated operating and approved design dose. Water systems that have source water exceeding 5 NTU turbidity may be required to install additional pretreatment and/or an online turbidimeter ahead of the UV water treatment device. An automatic shutdown valve shall be installed and operated in conjunction with the turbidimeter. Each owner shall have available on site at least one replacement lamp, a 5 micron replacement filter and, where applicable, a replacement cyst reduction filter and any other components necessary to keep the treatment system in service.

D. SEASONAL OPERATIONS

UV water treatment devices that are operated on a seasonal basis shall be inspected and cleaned prior to use at the start of each operating season. The UV water treatment system including the filters shall be disinfected prior to placing the water treatment system back into operation. A procedure for shutting down and starting up the UV treatment system shall be developed for or by each owner based upon manufacturer recommendations and submitted in writing to the review authority.

E. RECORD KEEPING AND ACCESS

A record shall be kept of the water quality test data, dates of lamp replacement and cleaning, a record of when the device was shutdown and the reason for shutdown, and the dates of prefilter replacement. The reviewing authority shall have access to the UV water treatment system and records. Water system owners will be required to submit operating reports and required sample results on a monthly or quarterly basis as required by the reviewing authority.

F. RAW WATER QUALITY CHARACTERISTICS

The water supply shall be analyzed for the following water quality parameters and the results shall be included in the UV application. Pretreatment is required for UV installations if the water quality exceeds any of the following maximum limits. When an initial sample exceeds a maximum limit, a check sample shall be taken and analyzed.

Parameter Maximum*

UV 254nm Absorption 0.155cm-1

Dissolved Iron 0.3 mg/L
Dissolved Manganese 0.05 mg/L
Hardness 120 mg/L
Hydrogen sulfide (if odor is present) Non-Detectable
Iron Bacteria None
pH 6.5 to 9.5
Suspended Solids 10 mg/L
Turbidity 1.0 NTU
Total Coliform 1,000/100 ML
E. Coli **
Cryptosporidium **
Giardia **

* Higher values may be acceptable to the reviewing authority if experience with similar water quality and reactors shows that adequate treatment is provided and there are no treatment problems or excessive maintenance required, or if the reactor was validated for parameters higher than these maximums.

** These organisms may indicate that the source is either a surface water or ground water under the direct influence of surface water and may require additional filtration pretreatment. Consult the reviewing authority for guidance.

Raw water quality shall be evaluated and pretreatment equipment shall be designed to handle water quality changes. Variable turbidity caused by rainfall events is of special concern.

POLICY STATEMENT ON INFRASTRUCTURE SECURITY FOR PUBLIC WATER SUPPLIES

Review of public water system security infrastructure and practices has shown an industry-wide vulnerability to intentional acts of vandalism, sabotage and terrorism. Protection from these types of threats must be integrated into all design considerations. Many public drinking water systems have implemented effective security and operational changes to help address this vulnerability, but additional efforts are needed. Security measures are needed to help ensure that public water suppliers attain an effective level of security. Design considerations need to address physical infrastructure security, and facilitate security related operational practices and institutional controls. Because drinking water systems cannot be made immune to all possible attacks, the design needs to address issues of critical asset redundancy, monitoring, response and recovery. All public water supplies need to identify and address security needs in design and construction for new projects and for retrofits of existing drinking water systems. The following concepts and items should be considered in the design and construction of new water system facilities and improvements to existing water systems:

1. Security shall be an integral part of drinking water system design. Facility layout shall consider critical system assets and the physical needs of security for these assets. Requirements for

submitting, identifying and disclosing security features of the design, and the confidentiality of the submission and regulatory review should be discussed with the reviewing authority.

2. The design should identify and evaluate single points of failure that could render a system unable to meet its design basis. Redundancy and enhanced security features should be incorporated into the design to eliminate single points of failure when possible, or to protect them when they cannot reasonably be eliminated.

3. Consideration should be made to ensure effective response and timely replacement of critical components that are damaged or destroyed. Critical components that comprise single points of failure (e.g., high volume pumps) that cannot be eliminated should be identified during design and given special consideration. Design considerations should include component standardization, availability of replacements and key parts, re-procurement lead times, and identification of suppliers and secure retention of component specifications and fabrication drawings. Readily replaceable components should be used whenever possible and provisions should be made for maintaining an inventory of critical parts.

4. Human access should be through controlled locations only. Intrusion deterrence measures (e.g., physical barriers such as fences, window grates and security doors; traffic flow and check-in points; effective lighting; lines of sight; etc.) should be incorporated into the facility design to protect critical assets and security sensitive areas. Effective intrusion detection should be included in the system design and operation to protect critical assets and security sensitive areas. All cameras and alarms installed for security purposes should include monitors at manned locations.

5. Vehicle access should be through controlled locations only. Physical barriers such as moveable barriers or ramps should be included in designs to keep vehicles away from critical assets and security sensitive areas. It should be impossible for any vehicle to be driven either intentionally or accidentally into or adjacent to finished water storage or critical components without facility involvement. Designated vehicle areas such as parking lots and drives should be separated from critical assets with adequate standoff distances to eliminate impacts to these assets from possible explosions of material in vehicles.

6. Sturdy, weatherproof, locking hardware must be included in the design of access for all tanks, vaults, wells, well houses, pump houses, buildings, power stations, transformers, chemical storage, delivery areas, chemical fill pipes, and similar facilities. Vents and overflows should be hardened through use of baffles or other means to prevent their use for the introduction of contaminants.

7. Computer based control technologies such as SCADA must be secured from unauthorized physical access and potential cyber attacks. Wireless and network based communications should be encrypted as deterrence to hijacking by unauthorized personnel. Vigorous computer access and virus protection protocols should be built into computer control systems. Effective data recovery hardware and operating protocols should be employed and exercised on a regular basis. All automated control systems shall be equipped with manual overrides to provide the option to operate manually. The procedures for manual operation including a regular schedule for exercising and insuring operator's competence with the manual override systems shall be included in facility operation plans.

8. Real time water quality monitoring with continuous recording and alarms should be considered at key locations to provide early warning of possible intentional contamination events.

9. Facilities and procedures for delivery, handling and storage of chemicals should be designed to ensure that chemicals delivered to and used at the facility cannot be intentionally released,

introduced or otherwise used to debilitate a water system, its personnel, or the public. Particular attention should be given to potentially harmful chemicals used in treatment processes (e.g., strong acids and bases, toxic gases and incompatible chemicals) and on maintenance chemicals that may be stored onsite (e.g., fuels, herbicides, paints, solvents).

POLICY STATEMENT ON ARSENIC REMOVAL

Arsenic in groundwater is an issue that many water systems must deal with following the maximum contaminant level revision from 50 parts per billion (ppb) to 10 ppb on January 22, 2006. Several technologies are available to remove arsenic, from fairly simple to more complex. In much of the Upper Midwest, arsenic typically exists as As (III) in groundwater, and as As (V) in surface waters. Arsenic in the form of As (V) is easier to remove due to its insolubility and negative charge. Arsenic As (III) can be changed to As (V) by a simple oxidation process. With the different removal technologies comes a wide range of monetary investment. In addition, the issue of discharging concentrated waste water and/or disposal of solid wastes must be resolved. The safe and proper disposal of all related treatment wastes must comply with all local, state, federal and provincial requirements. When the maximum contaminant limit (MCL) for arsenic is exceeded, it is recommended that the treatment is capable of reducing arsenic levels in the water to one-half the MCL (currently 5 ppb) or less. The following list provides information on different types of typical arsenic treatment technologies and options for optimization:

Adsorptive Media - Uses metal oxide coatings, usually iron, titanium or aluminum, on the filter media to remove arsenic. Pre- and post-adjustment of pH will enhance removal rates and reduce corrosivity. This method needs chemical oxidation of arsenic, iron and manganese (if present), a pre-filter to remove iron and manganese to prevent fouling of the adsorptive media (if iron levels are too high [near or above 1.0 ppm]), followed by the adsorptive filter media. Costs for implementing this technology may be low to moderate if a system currently has an iron and/or manganese filter. High levels of iron, sulfate, and dissolved solids may cause interference or reduce the treatment efficiency.

Oxidation/Filtration (Iron & Manganese removal) - This method uses chemical oxidation of arsenic, iron and manganese with free chlorine, potassium permanganate (KMnO₄), ozone or manganese dioxide with a manganese greensand, anthracite, pyrolusite, or other proprietary filter media. The water is allowed detention time and filtration after chemical oxidation. Water with low iron (less than a 20 to 1 ratio of iron to arsenic) may need additional iron in the form of ferric chloride or ferric sulfate to increase arsenic removal efficiencies.

Coagulation/Filtration - Typically chemical oxidation of arsenic, iron and manganese, pre- and post-adjustment of pH (to enhance coagulation; reduce corrosivity), the use of ferric chloride, ferric sulfate, or alum as a coagulant, use a polymer (filter aid or enhanced coagulation), and settling time (sedimentation) to remove arsenic. Other contaminants may be removed in this process. Sulfate may cause interference or reduce treatment efficiency.

Other Types of Treatment Technologies

Anion Exchange - Chloride (strong-base) sulfate-selective or nitrate-selective resins, are used to remove contaminants. This process may also require the chemical oxidation of arsenic, iron and manganese (if present), and pre-filters to maximize contaminant removal, and to prevent fouling of the exchange resin. Post-treatment adjustment of pH is required to reduce corrosivity. Treatment

columns may be in parallel or series (avoid sulfate, nitrate and arsenic breakthrough, and avoid lowered pH breakthrough immediately after regeneration). Treatment may use anion exchange after cation exchange to remove hardness (mixed beds not recommended - anion resins are lighter and column becomes service intensive). Other contaminants that can be removed include sulfate (sulfate-selective resins); nitrate (nitrate-selective resins); and hardness (mixed cation/anion beds). Iron, sulfate, and dissolved solids may cause interference or reduce treatment efficiency.

Electrodialysis/Electrodialysis Reversal - Uses an electrical charge of a reverse osmosis (R.O.) membrane to remove arsenic. Chemical oxidation of arsenic, iron and manganese with filtration is used to remove oxidized iron and manganese to prevent fouling of the R.O. membrane. Pre- and post-adjustment of pH may be needed to prevent scaling, to enhance filtration, and to reduce corrosivity. Other contaminants that may be removed using this technology include hardness, dissolved solids, nitrates, and sulfates. If iron and manganese are too high, this may cause interference with the arsenic removal process.

Membrane Filtration (Micro, Ultra, Nanofiltration, and Reverse Osmosis) - Membrane removal utilizes chemical pre-oxidation (except when using polypropylene membranes), a pre-filter to remove oxidized iron and manganese to prevent fouling of the membranes), pre- and post-adjust pH (prevent scaling, enhance filtration; reduce corrosivity). The treatment can also use ferric chloride or ferric sulfate as a coagulant. Iron, manganese, and other dissolved solids may cause interference or reduce treatment efficiency. Reverse osmosis membranes will also remove hardness in the water.

Lime Softening - This technology is based on the optimization of $Mg(OH)_2$ precipitation. High iron concentrations are desired for optimal arsenic removal. Waters with low dissolved iron may require the addition of ferric chloride or ferric sulfate. Hardness may also be removed in this process. Other issues include the disposal of lime sludge, and the high labor intensity of handling lime.

INTERIM STANDARD - NITRATE REMOVAL USING SULFATE SELECTIVE ANION EXCHANGE RESIN

Four treatment processes are generally considered acceptable for Nitrate/Nitrite removal. These are anion exchange, reverse osmosis, nanofiltration and electrodialysis. Although these treatment processes, when properly designed and operated will reduce the nitrate/nitrite concentration of the water to acceptable levels, primary consideration shall be given to reducing the nitrate/nitrite levels of the raw water through either obtaining water from an alternate water source or through watershed management. Reverse osmosis nanofiltration or electrodialysis should be investigated when the water has high levels of sulfate or when the chloride content or dissolved solids concentration is of concern.

Most anion exchange resins used for nitrate removal are sulfate selective resins. Although nitrate selective resins are available, these resins typically have a lower total exchange capacity.

SPECIAL CAUTION

If a sulfate selective anion exchange resin is used beyond bed exhaustion, the resin will continue to remove sulfate from the water by exchanging the sulfate for previously removed nitrates resulting in treated water nitrate levels being much higher than raw water levels. Therefore it is extremely important that the system not be operated beyond design limitations.

PRE-TREATMENT REQUIREMENTS

An evaluation shall be made to determine if pretreatment of the water is required if the combination of iron, manganese, and heavy metals exceeds 0.1 milligrams per liter.

DESIGN

Anion exchange units are typically of the pressure type, down flow design. Although a pH spike can typically be observed shortly before bed exhaustion, automatic regeneration based on volume of water treated should be used unless justification for alternate regeneration is submitted to and approved by the reviewing authority. A manual override shall be provided on all automatic controls. A minimum of two units must be provided. The total treatment capacity must be capable of producing the maximum day water demand at a level below the nitrate/nitrite MCL. If a portion of the water is bypassed around the unit and blended with the treated water, the maximum blend ratio allowable must be determined based on the highest anticipated raw water nitrate level. If a bypass is provided, a totaling meter and a proportioning or regulating device or flow regulating valves must be provided on the bypass line.

EXCHANGE CAPACITY

Anion exchange media will remove both nitrates and sulfate from the water being treated. The design capacity for nitrate and sulfate removal expressed as CaCO₃ should not exceed 16,000 grains per cubic foot (37g/l) when the resin is regenerated with 10 pounds of salt per cubic foot (160 g/l) of resin when operating at 2 to 3 gallons per minute per cubic foot (0.27 to 0.4 L/min per litre). However, if high levels of chlorides exist in the raw water, the exchange capacity of the resin should be reduced to account for the chlorides.

FLOW RATES

The treatment flow rate should not exceed 7 to 8 gallons per minute per square foot of bed area (29 to 32 cm/minute down flow rate). The back wash flow rate should be 2 to 3 gallons per minute per square foot of bed area (8 to 12 cm/minute rise rate) with a fast rinse approximately equal to the service flow rate.

FREEBOARD

Adequate freeboard must be provided to accommodate the backwash flow rate of the unit.

MISCELLANEOUS APPURTENANCES

The system shall be designed to include an adequate under drain and supporting gravel system, brine distribution equipment, and cross connection control.

MONITORING

When ever possible, the treated water nitrate/nitrite level should be monitored using continuous monitoring and recording equipment. The continuous monitoring equipment should be equipped with a high nitrate level alarm. If continuous monitoring and recording equipment is not provided, the finished water nitrate/nitrite levels must be determined (using a test kit) no less than daily, preferably just prior to regeneration of the unit.

WASTE DISPOSAL

Generally, waste from the anion exchange unit should be disposed in accordance with Section 4.11.2 of these Standards. However, prior to any discharge, the reviewing authority must be contacted for wastewater discharge limitations or NPDES requirements.

ADDITIONAL LIMITATIONS

Certain types of anion exchange resins can tolerate no more than 0.05 mg/L free chlorine. When the applied water will contain a chlorine residual, the anion exchange resin must be a type that is not damaged by residual chlorine.

INTERIM STANDARD -USE OF CHLORAMINE DISINFECTANT FOR PUBLIC WATER SUPPLIES

Chloramination is an application of ammonia and chlorine, with ammonia addition usually downstream of the application of chlorine at a proper mass ratio of chlorine to ammonia to produce a combined chlorine residual predominantly in form of monochloramine. Proper chlorine to ammonia ratio must be maintained to prevent the formation of dichloramine and trichloramine which create taste and odor in drinking water.

Monochloramine is rarely suitable for use as a primary disinfectant because it requires very long contact time to achieve adequate disinfection at the normally used concentration. Because of its high persistence characteristics, monochloramine is more commonly used to maintain a chlorine residual in the water distribution system as a secondary disinfectant.

Chloramine residual is more stable and longer lasting than free chlorine, and it provides better protection against bacterial regrowth in water distribution systems including large storage tanks, lower flow demand and dead-end water mains. As a result, it is more effective in controlling biofilm growth in the water distribution system. Chloramine is not as reactive as chlorine with organic material in water, thereby producing substantially less disinfection by-products such as trihalomethanes in the water distribution system. However, chloramine may provide less protection from contamination of the distribution system through cross connections, water main breaks and other causes. Unlike most substances added to water for treatment purposes, chloramine cannot be prepared at high concentrations. It can only be made by addition of ammonia to pre-chlorinated water or by adding chlorine to water containing low concentrations of ammonia. Contact of high concentrations of chlorine with ammonia or ammonium salts must be avoided to prevent the formation of nitrogen trichloride which is a sensitive and violently explosive substance. Operating authorities who wish to modify disinfectant practices by using chloramine must show the reviewing authority clear evidence that bacteriological and chemical protection of consumers will not be compromised in any way and that aspects of chloramination mentioned below are considered in any permit application.

1. Chloramine, which is less powerful than free chlorine, may be suitable for disinfection of some ground water supplies but it is inadequate in strength for primary disinfection of surface waters.
2. Chloramine can be suitable for protecting potable water in distribution systems against bacterial contamination. The chloramine tends to remain active for longer periods and at greater distances from the plant than free chlorine. Chloramine concentrations should be maintained higher than for chlorine to avoid nitrifying bacterial activity. A range of 1-2 mg/L, measured as combined chlorine, on entry to the distribution system and greater than 1 mg/L at the system extremities is

recommended. Chloramine can be less odorous than chlorine so these concentrations may be tolerated well by consumers.

3. Suitable commercial sources of ammonia for chloramine production are either ammonia gas or water solutions of ammonia or ammonium sulphate. Ammonia gas is supplied as compressed liquid in cylinders which must be stored in separate facilities designed as for chlorine gas. Ammonia solutions must be stored in containment with adequate cooling to prevent gas release from storage and gas release must be handled with pressure relief systems. Absorption/neutralization systems for ammonia gas leaks/spills must be designed specially for ammonia. Ammonium sulphate is available as free flowing powdered solid which must be stored in cool dry conditions and dissolved in water for use.

4. Thorough and reasonably rapid mixing of chlorine and ammonia in the main plant stream shall be arranged so as to avoid formation of organic chloramines and of odorous dichloramine. Sufficient ammonia must be added to provide at least a small excess (more than one part of ammonia to between 3 and 5 parts of chlorine) over that required to convert all the free chlorine present to chloramine.

5. Addition of ammonia gas or ammonia solution will increase the pH of the water and addition of ammonium sulphate depresses the pH. The actual pH shift may be small in well buffered water but the effects on disinfectant power and corrosiveness of the water may require consideration. Ammonia gas forms alkaline solutions which may cause local plugging by lime deposition. Where hard water is to be treated, a side stream of pre-softened water may be needed for ammonia dilution so as to reduce plugging problems.

6. The use of chloramine in distribution systems which are not well maintained by flushing, swabbing and other regular routine maintenance activities can lead to local loss of disinfectant residual, increased nitrifying bacterial activity and, possibly over a period of time, to persistent high coliform bacterial counts which may not respond to reversion to the use of free chlorine. Early detection of nitrifying bacteria activity may be made by checking for reduced dissolved oxygen, elevated free ammonia, elevated HPC, and elevated nitrite and nitrate levels.

7. Chloramine in water is considerably more toxic to fish and other aquatic organisms than free chlorine. Consideration must therefore be given to the potential for leaks to contaminate and damage natural water course eco-systems. Kidney dialysis treatment can be upset by use of chloraminated water. Medical authorities, hospitals and commercial and domestic aquarium keepers should be notified so they can arrange for precautions to be taken.

INTERIM STANDARD - MEMBRANE TECHNOLOGIES FOR PUBLIC WATER SUPPLIES

Membrane technologies have a wide range of applications from the use of reverse osmosis for desalination, inorganic compound removal, and radionuclide removal to the use of lower pressure membranes for removal of surface water contaminants such as giardia and cryptosporidium. Membrane technologies are typically separated into four categories based on membrane pore size: reverse osmosis, nanofiltration, ultrafiltration, and microfiltration. When using membranes for treatment of surface water or groundwater under the direct influence of surface water the reviewing agency should be contacted to determine inactivation/removal credits for the specific membrane and treatment objective. The following items should be considered when evaluating the applicability of membrane processes.

1. Treatment objectives. The selection of the specific membrane process should be matched to the desired treatment objectives. Removal is generally related to pore size and as such the larger pore size membranes are not appropriate for applications such as inorganic compound or radionuclide removal.
2. Water quality considerations. A review of historical source raw water quality data, including turbidity and/or particle counts, seasonal changes, organic loading, microbial activity, and temperature differentials as well as other inorganic and physical parameters should be conducted. The data should be used to determine feasibility and cost of the system. The degree of pre-treatment may also be ascertained from the data. Design considerations and membrane selection at this phase must also address the issue of target removal efficiencies and system recovery versus acceptable transmembrane pressure differentials. On surface water supplies, pre-screening or cartridge filtration may be required. The source water temperature can significantly impact the flux of the membrane under consideration. At low water temperatures, the flux can be reduced appreciably (due to higher water viscosity and resistance of the membrane to permeate), possibly impacting process economics by the number of membrane units required for a full scale facility. Seasonal variation of design flow rates may be based on documented lower demand during colder weather.
3. Pilot study/preliminary investigations. Prior to initiating the design of a membrane treatment facility, the reviewing agency should be contacted to determine if a pilot plant study will be required. In most cases, a pilot plant study will be required to determine the best membrane to use, the need for pretreatment, type of post treatment, the bypass ratio, the amount of reject water, system recovery, process efficiency, particulate/organism removal efficiencies, cold and warm water flux, fouling potential, operating and transmembrane pressure and other design and monitoring considerations. Any virus removal credit must also be documented through an appropriate piloting process. The reviewing authority should be contacted prior to conducting the pilot study to establish the protocol to be followed.
4. Challenge Testing. Membranes treating surface waters or groundwater under the direct influence of a surface water must be challenge tested to establish a product specific maximum *Cryptosporidium* log removal credit.
5. Pretreatment. Acceptable feedwater characteristics are dependent on the type of membrane and operational parameters of the system. Without suitable pretreatment or acceptable feed water quality, the membrane may become fouled or scaled and consequently shorten its useful life. For reverse osmosis and nanofiltration processes pretreatment is usually needed for turbidity reduction, iron or manganese removal, stabilization of the water to prevent scale formation, microbial control, chlorine removal (for certain membrane types), and pH adjustment. Usually, at a minimum, cartridge filters should be provided for the protection of the reverse osmosis or nanofiltration membranes against particulate matter.
6. Membrane materials. Two types of membranes are typically used for reverse osmosis and nanofiltration. These are cellulose acetate based and polyamide composites. Membrane configurations typically include tubular, spiral wound and hollow fiber. Microfiltration (MF) and nanofiltration (NF) membranes are most commonly made from organic polymers such as: cellulose acetate, polysulfones, polyamides, polypropylene, polycarbonates, and polyvinylidene. The physical configurations include: hollow fiber, spiral wound, and tubular. Operational conditions and

useful life vary depending on type of membrane selected, quality of feed water, and process operating parameters. Some membrane materials are incompatible with certain oxidants. If the system must rely on pre-treatment oxidants for other purposes, for example, zebra mussel control, taste and odor control, or iron and manganese oxidation, the selection of the membrane material becomes a significant design consideration.

7. Useful life of membranes. Membrane replacement represents a major component in the overall cost of water production. The life expectancy of a particular membrane under consideration should be evaluated during the pilot study or from other relevant available data. Membrane life may also be reduced by operating at consistently high fluxes. Membrane replacement frequency is a significant factor in operation and maintenance cost comparisons in the selection of the process.

8. Treatment efficiency. Reverse osmosis (RO) and nanofiltration (NF) are highly efficient in removing metallic salts and ions from the raw water. Efficiencies, however, do vary depending on the ion being removed and the membrane utilized. For most commonly encountered ions, removal efficiencies will range from 85% to over 99%. Organics removal is dependent on the molecular weight, shape and charge of the organic molecule and the pore size of the membrane utilized. Removal efficiencies may range from as high as 99% to less than 30%, depending on the membrane type and organic being considered.

9. Power consumption. Power consumption may be a significant cost factor for reverse osmosis plants. The power consumption of a particular membrane under consideration should be evaluated during the pilot study or from other relevant data.

10. Bypass water. Reverse osmosis (RO) permeate will be virtually demineralized. Nanofiltration (NF) permeate may also contain less dissolved minerals than desirable. The design should provide for a portion of the raw water to bypass the unit to maintain stable water within the distribution system and to improve process economics as long as the raw water does not contain unacceptable contaminants. Alternative filtration is required for bypassed surface water or ground water under the direct influence of surface water.

11. Reject water. Reject water from reverse osmosis and nanofiltration membranes may range from 10% to 50% of the raw water pumped to the reverse osmosis unit. For most brackish waters and ionic contaminant removal applications, reject is in the 10-25% range while for seawater it could be as high as 50%. The reject volume should be evaluated in terms of the source availability and from the waste treatment availabilities. The amount of reject water from a unit may be reduced to a limited extent by increasing the feed pressure to the unit. However, this may result in a shorter membrane life. Acceptable methods of waste disposal typically include discharge to a municipal sewer system, to waste treatment facilities, or to an evaporation pond.

12. Backflushing or cross flow cleansing. Automated periodic backflushing and cleaning is employed on microfiltration and ultrafiltration on a timed basis or once a target transmembrane pressure differential has been reached. Back flushing volumes can range from 5 -15 percent of the permeate flow depending upon the frequency of flushing/cleaning and the degree of fouling and this should be considered in the treatment system sizing and the capacity of the raw water source.

13. Membrane cleaning. The membrane must be periodically cleaned with acid, detergents and possibly disinfection. Method of cleaning and chemicals used must be approved by the state reviewing agency. Care must be taken in the cleaning process to prevent contamination of both the raw and finished water system. Cleaning chemicals, frequency and procedure should follow membrane manufacturer's guidelines. Cleaning chemicals should be NSF/ANSI Standard 60 certified.

14. Membrane integrity and finished water monitoring. An appropriate level of direct and indirect integrity testing is required to routinely evaluate membrane and housing integrity and overall filtration performance. Direct integrity testing may include pressure and vacuum decay tests for MF& UF and marker-based tests for NF & RO. These are usually conducted at least once per day. Indirect monitoring options may include particle counters and/or turbidity monitors and should be done continuously. Consult the appropriate regulatory agency regarding specific process monitoring requirements.
15. Cross connection control. Cross connection control considerations must be incorporated into the system design, particularly with regard to chemical feeds and waste piping used for membrane cleaning, waste stream and concentrate. Typical protection includes block & bleed valves on the chemical cleaning lines and air gaps on the drain lines.
16. Redundancy of critical components. Redundancy of critical control components including but not limited to valves, air supply, and computers shall be required as per the reviewing authority.
17. Post treatment. Post treatment of water treated using reverse osmosis or nanofiltration typically includes degasification for carbon dioxide (if excessive) and hydrogen sulfide removal (if present), pH and hardness adjustment for corrosion control and disinfection as a secondary pathogen control and for distribution system protection.
18. Operator training. The ability to obtain qualified operators must be evaluated in selection of the treatment process. The necessary operator training shall be provided prior to plant startup.

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The Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers in 1950 created a Water Supply Committee consisting of one associate from each state represented on the Board. A representative from the Province of Ontario was added in 1978. Throughout this document the term state shall mean a representative state or the Province of Ontario. The Committee was assigned the responsibility for reviewing existing water works practices, policies, and procedures, and reporting its findings to the Board. The report of the Water Supply Committee was

first published in 1953, and subsequently has been revised and published in 1962, 1968, 1976, 1982, 1987, 1992, 1997, 2003 and 2007.

This document includes the following:

1. Policy Statements – Preceding the standards are policy statements of the Board concerning water works design, practice, or resource protection. Some policy statements recommend an approach to the investigation of innovative treatment processes which have not been included as part of the standards because sufficient confirmation has not yet been documented to allow the establishment of specific limitations or design parameters. Other policy statements recommend approaches, alternatives or considerations in addressing a specific water supply issue and may not develop into standards.
2. Interim Standards - Following the policy statements are interim standards. The interim standards give design criteria which are currently being used for new treatment processes, but the use of the criteria is limited and insufficient for recognition as a recommended standard.