LEGEND: **DRAFT 07/015/2014**
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**Blue bold** text is new

## 10 CSR 20-8.180 Biological Treatment

*PURPOSE: The following criteria have been prepared as a guide for the design of biological treatment facilities. This rule is to be used with rules 10 CSR 20-8.110[–]* ***through*** *10 CSR 20-8.220 for the planning and design of the complete treatment facility. This rule reflects the minimum requirements of the Missouri Clean Water Commission [as]* ***in*** *regards* ***to*** *adequacy of design, submission of plans, approval of plans and approval of completed [sewage works]* ***wastewater treatment facilities. It is not reasonable or practical to include all aspects of design in these standards. The design engineer should obtain appropriate reference materials which include but are not limited to: copies of all ASTM International standards pertaining to wastewater treatment facilities and appurtenances, design manuals such as Water Environment Federation's Manuals of Practice, and other wastewater treatment facilities design manuals containing principles of accepted engineering practice.*** *Deviation from these minimum requirements will be allowed where sufficient documentation is presented to justify the deviation. These criteria are taken largely from* ***the 2004 edition of*** *Great Lakes-Upper Mississippi River Board of State [Sanitary Engineers]* ***and Provincial Public Health and Environmental Managers*** *Recommended Standards for [Sewage Works]* ***Wastewater Facilities*** *and are based on the best information presently available. These criteria were originally filed as 10 CSR 20-8.030. It is anticipated that they will be subject to review and revision periodically as additional information and methods appear. [Addenda or supplements to this publication will be furnished to consulting engineers and city engineers. If others desire to receive addenda or supplements, please advise the Clean Water Commission so that the name can be added to the mailing list.]*

*Editor's Note: The secretary of state has determined that the publication of this rule in its entirety would be unduly cumbersome or expensive. The entire text of the material referenced has been filed with the secretary of state. This material may be found at the Office of the Secretary of State or at the headquarters of the agency and is available to any interested person at a cost established by state law.*

(1) Definitions. Definitions as set forth in the Clean Water Law and 10 CSR 20-2.010 shall apply to those terms when used in this rule, unless the context clearly requires otherwise. Where the terms **"**shall**"** and **"**must**"** are used, they are to mean a mandatory requirement insofar as approval by the *[agency*] **Missouri Department of Natural Resources (department)** is concerned, unless justification is presented for deviation from the requirements. Other terms, such as **"**should,**" "**recommend,**" "**preferred**"** and the like, indicate [discretionary requirements on the part of the agency and deviations are subject to individual consideration.] **the preference of the department for consideration by the design engineer.**

**(A) Deviations. Deviations from these rules may be approved by the department when engineering justification satisfactory to the department is provided. Justification must substantially demonstrate in writing and through calculations that a variation(s) from the design rules will result in either at least equivalent or improved effectiveness.**

**Deviations are subject to case-by-case review with individual project consideration.**

*[(2) Exceptions. This rule shall not apply to facilities designed for twenty-two thousand five hundred gallons per day (22,500 gpd) (85.4m$^3$)]] or less (see 10 CSR 20-8.020 for the requirements for those facilities).]*

**(2) Applicability. This rule shall apply to all wastewater treatment facilities. This rule shall supersede when there is a conflict with 10 CSR 20-8.020.**
**(3) Recirculating Media Filters. Recirculating media filters are generally considered suitable for treatment of small flows or for flows which are highly intermittent or seasonal.**

**(A) Location. Recirculating media filters following primary treatment shall be located a minimum of two hundred feet (200') (60.96 m) from future or existing residences or other establishments. Siting of recirculating media filters shall consider access needed for maintenance and repairs by construction equipment. Recirculating media filters following activated sludge treatment plants shall be located at least fifty feet (50')(15.24 m) from any existing or future residence. The possibility of intermittent objectionable odors occurring during dosing should be considered when locating these systems.**

**(B) Primary Treatment. Primary treatment shall be provided prior to all forms of recirculating media filtration to prevent fouling of the filter from suspended solids, grease, and from excessive bacterial growth due to biochemical oxygen demand (BOD) overloading. To accomplish this, the primary treatment process shall provide a quiescent environment to promote settling of suspended particles, as well as allowing for contact between the influent wastewater and naturally occurring anaerobic bacteria. If the wastewater is domestic in origin, settleable and floatable solid separation by a properly sized two-compartment septic tank with effluent baffle screening, or equivalent wastewater sedimentation/initial treatment unit, will suffice.**

**(C) Equalization Tank. The size of the equalization tank should be determined through a hydraulic analysis of the system that distributes the compressed flow over a twenty to twenty-four hour (20 to 24) time period and eliminates surcharging of the sand filter. Flow equalization should be provided when the total daily flow occurs over a period of twelve hours or less and should be sized based on a hydraulic analysis of hourly flows. The minimum size equalization tank should be 0.5 times total daily flow. The equalization tank mixture is pumped to the recirculation tank at a rate that equalizes total flow over a twenty-four (24) hour period. A timer with a high-level override control should operate the pumps in the equalization tank.**

**(D) Filter Bed.**

1. **Filter bottoms are generally constructed of unfilled earth, however liners or poured concrete bottoms may be required in areas subject to potential groundwater contamination.**
2. **Filter walls shall be of concrete or masonry. They shall extend at least six inches (6") (15.24 cm) above the top of the media bed and at least six inches (6") (15.24 cm) above the adjacent ground surface.**
3. **The filter surface should be protected from runoff and diversion ditches. Berms will be required as the need indicates.**
4. **Filters may be covered to protect against severe weather conditions and to avoid encroachment of weeds or animals. The cover also serves to reduce odor conditions. Covers may be constructed of treated wooden planks, galvanized metal or other suitable materials. Screens or hardware cloth mounted on wooden frames may also serve to protect filter surfaces. Where weather conditions dictate, covers should be insulated. A space of twelve to twenty-four inches (12–24")(30.48-60.96 cm) should be allowed between the insulated cover and sand surface.**
5. **Dual filters each sized for the design flow are required for treating septic tank effluent. Single filters are adequate for extended aeration plant effluent except that plants receiving and treating wastewaters stronger than domestic type waste (less than three hundred (300) mg/l influent BOD) shall be provided with dual filters. A diversion box shall be provided where two (2) or more beds are used.**
6. **Distribution piping shall be installed on top of the filter media. The filter manifold should be designed with a minimum 5foot (1.52 m) pressure residual at the most remote orifice, and should have no more than a ten percent (10%) differential in flow between any two orifices. A flushing valve enclosed in a valve box installed at grade shall be provided at the distal end of each distribution pipe. Provisions shall be incorporated to allow for cleaning the distribution lines with a bottle washer and plumber's snake.**

**(E) Dosing**

1. **Daily dose frequencies should be based on media grain size, wastewater strength and operating temperatures.**
2. **Dosing of the filter should provide for flooding the bed to a depth of approximately two inches (2") (5.08 cm) or one and one-fourth gallons (1.25 gals.)(0.167 ft3) per square foot.**
3. **Optimum pumping cycles are for one continuous cycle every thirty (30) minutes for forty-eight (48) cycles per day with the off cycle set for approximately twenty-five (25) minutes. The on cycle should be set so that the orifice discharge per dose cycle does not exceed two (2) gallons (0.26 ft3) per orifice.**
4. **Adjustable timers should be provided so that dosing schedules can be modified as site conditions warrant. Both timer and float switch controls are required; timers shall be used as the primary method of operation. Float switches, for use in the event of timer malfunction, shall be wired in parallel with the timer to control the pump during periods of high or low wastewater flows. Proper sizing of the recirculation tank should minimize float switch operation.**

**(F) Loading**

1. **Hydraulic Loading. The hydraulic loading for media filters should be less than three and half gallons (3.5)(0.468 ft3) per day per square foot when treating septic tank effluent and less than eight gallons (8 gals)(1.069ft3) per day per square foot when treating the effluent from an extended aeration treatment plant. In choosing what loading rate to use, the engineer should consider effective size of the media and maintenance requirements.**
2. **Organic Loading. The organic loading rate should be less than 0.003 lbs of applied BOD per square foot per day.**
3. **For systems designed to nitrify and reduce nitrogen, the alkalinity of the influent shall be determined. If the alkalinity is low the design should include a method for adding and monitoring alkalinity to the system. Approximately eight milligrams (8 mg) of alkalinity are consumed for every milligram of ammonia oxidized.**

**(G) Media Characteristics. The media is any of a number of physical structures whose sole purpose is to provide a surface to support biological growth. Commonly used media includes rock, gravel, and sand of various sizes, textile media, and peat. Finely crushed limestone or dolomite is not acceptable. The media must be free of any clay, limestone or appreciable amounts of organic material.**

1. **The media depth shall not be less than thirty-three inches (33")(83.82 cm). The depth of the fine filtering media shall be twenty-four inches (24")(60.96 cm) at a minimum. A coarser material shall be used below the fine filtering media. The lower media depth shall be great enough to cover the under drain pipes, so where four inch (4")(10.16 cm) diameter under drains are used, a lower coarse media depth of six inches (6")(15.24 cm) is sufficient. An intermediate layer of three inches (3") (7.62 cm) shall be between the coarse and fine media to prevent migration of fine media into the lower layer.**
2. **The uniformity coefficient should be less than 2.5 and shall not exceed 3.5.**
3. **Effective Size: 3 mm to 5 mm.**
4. **Particle Size Distribution:**

| Sieve | Particle Size | Percent Passing by Weight |
|---|---|---|
| 3/8 inch | 9.50 mm | 100% |
| No. 4 | 4.75 mm | 0 to 95% |
| No. 8 | 2.36 mm | 0 to 2% |
| No. 30 | 0.60 mm | 0 to 0.1% |

**5. No sand shall be used unless a sieve analysis has been performed on the material delivered to the site. A copy of the report on sieve analysis shall be submitted to the department with the final operating permit application.**

**(H) Recirculation . Wastewater which has been treated in the recirculating media filter, collects at the bottom of the filter through an underdrain and a portion is returned to the recirculating/ mixing tank.**

**1. The return flow must be split to direct a minimum of seventy-five to eighty-five percent (75-85%) of the treated wastewater back to the recirculating/mixing tank.**
**2. The recirculation ratio provided should be 5:1, but shall be no less than 3:1.**
**3. To encourage mixing of fresh influent with partially treated recirculating return filtrate, the return line from the filter should enter the recirculating/mixing tank at the same end of the tank as the influent from the septic tank and at the opposite end from the recirculating pump.**
**4. The return piping from the sand filter should enter at the inlet end of the recirculation and equalization tanks remote from the pump location, to allow mixing of septic effluent with treated recirculated filtrate.**
**5. Float switches shall be wired in parallel with the timer to control the pump during periods of excessive wastewater flows, and in event of timer malfunction. Both timer and float switch controls are required.**
**6. To protect the pump and the distribution pipe network orifices, the outlet of the septic tank must include screening of the effluent unless screening of the pump is provided.**
**7. In the event of low levels in the recirculating/mixing tank, to protect the pump by assuring adequate pump submergence, a redundant off/low level alarm control float is recommended. The redundant off/low level alarm should be installed in accordance with the pump manufacturer's recommendations to assure adequate pump submergence.**

**(I)Underdrain Systems**

**1. Filtrate shall be collected and discharged from the bottom of the sand filter by either a gravity flow underdrain system or a pumped system. A single pipe in the middle of the filter shall not be used as an underdrain. The design shall allow the underdrain area to remain aerobic. Piping should be sized large enough to allow for the rapid return of the filtrate to the recirculation and equalization tanks to prevent ponding in the filter.**
**2. Underdrain pipes shall be slotted PVC or HDPE pipes with a minimum four inch (4") (10.16 cm) diameter with quarter-inch (0.25")(0.635 cm) slots, two inches (2")(5.08 cm) long and spaced four inches (4")(10.16 cm) apart.**
**3. A minimum of two underdrain pipes shall be provided for each filter section. The pipes shall be placed upon the impervious liner at the bottom of the sand filter with the slots facing upward. The distal end of the underdrain shall be brought to grade and covered with a removable cap housed in a protective chamber.**
**4. The underdrain pipe shall be installed at a half to one percent (0.5-1.0%) grade and be connected to a manifold outside the filter.**
**5. Underdrain pipes should be spaced a maximum of eight feet (8')(2.43m) on center.**
**6. An observation pipe consisting of a four inch (4")(10.16 cm) slotted pipe, capped at the bottom and wrapped in filter cloth shall be installed in the center of each side of the split sand filter and brought to finished grade and covered with a removable cap.**
**7. To encourage mixing of fresh influent with partially treated recirculating return filtrate, the return line from the filter should enter the recirculating/mixing tank at the same end of the tank as the influent from the septic tank and at the opposite end from the recirculating pump.**

**(J) Distribution Systems**

1. **Distribution is often provided through pipelines and directed on splash plates located at the center or corners of the sand surface. Occasionally troughs or spray nozzles are employed as well and ridge and furrow application has been successful during winter operation in severe climatic conditions.**
2. **Distribution to the filter may be by means of troughs laid on the surface, pipelines discharging to splash plates located at the center or corners of the filter or spray distributors. Care must be taken to insure that lines discharging directly to the filter surface do not erode the sand surface. The use of curbs around splash plates or large stones placed around the periphery of the plates will reduce the scour.**
3. **When troughs or point discharges are used, they should be located so that the maximum lateral travel over the sand is not more than twenty feet (20') (6.096m). The design of the distribution system shall assure that the effluent will be evenly distributed from each point discharge or trough or spray nozzle.**
4. **Dosed distribution boxes may be appropriate in some situations. A layer of washed pea gravel placed over the filter media may also be employed to avoid surface erosion. This practice will create maintenance difficulties when it is time to rake or remove a portion of the media surface.**
5. **The filter manifold should be designed with a minimum five foot(5') pressure residual at the most remote orifice, and should have no more than a ten percent (10%) differential in flow between any two (2) orifices. A flushing valve enclosed in a valve box installed at grade shall be provided at the distal end of each distribution pipe.**
6. **Provisions shall be incorporated to allow for cleaning the distribution lines with a bottle washer and plumber's snake.**

(*[3]***4**) Trickling Filters.

(A) General. Trickling filters may be used for treatment of *[sewage]* **wastewater** amenable to treatment by aerobic biologic processes. **The trickling filter is a non-submerged attached-growth process.** Trickling filters shall be preceded by effective settling tanks equipped with scum and grease collecting devices or other suitable pretreatment facilities. Filters shall be designed so as to provide the reduction in carbonaceous and/or nitrogenous oxygen demand in accordance with 10 CSR 20-7.015, Effluent Regulations and 10 CSR 20-7.031, Water Quality Standards, or to properly condition the sewage for subsequent treatment processes. **Multi-stage filters should be considered if needed to meet more stringent effluent standards.**

(B) Hydraulics.

1. **Trickling filters are classified according to applied hydraulic loading, including recirculation, in million gallons per day (mgd) per acre of filter media surface area and influent organic loadings in pounds of five-day biochemical oxygen demand ($BOD_5$) per day per 1,000 cubic feet of filter media, The following factors shall be the basis for the selection of the design hydraulic and organic loadings:**
   - **A. Strength of the influent wastewater;**
   - **B. Effectiveness of pretreatment;**
   - **C. Type of filter media; and**
   - **D. Treatment efficiency required.**
2. **A trickling filter is classified as:**
   - **A. A roughing filter, which provides at least fifty percent (50%) but not more than seventy-five percent (75%) removal of soluble $BOD_5$;**
   - **B. A secondary treatment filter, which provides the required settled effluent $BOD_5$ and total suspended solids (TSS);**
   - **C. A combined $BOD_5$ and nitrifying filter, which provides the required settled effluent $BOD_5$, ammonia-nitrogen ($NH_4$-N), and TSS; or**
   - **D. A tertiary nitrifying filter, which provides the required settled effluent $NH_4$-N, if the influent to a trickling filter is a clarified secondary effluent, that has a five-day biochemical oxygen demand ($BOD_5$) to total Kjeldahl nitrogen**

**(TKN) ratio of equal to or greater than (≥) 1.0 and soluble $BOD_5$ of less than or equal to (≤) 12 milligrams per liter (mg/l).**

3. **The following table provides the hydraulic and organic loadings for different classes of trickling filters:**

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| **Design Parameter** | **Units** | **Low Rate** | **Intermediate Rate** | **High Rate** | **Super High Rate** | **Roughing** | **Two Stage** | **Nitrifying** |
|---|---|---|---|---|---|---|---|---|
| **Filter Media** | | **Rock, Slag** | **Rock, Slag** | **Rock** | **Manufactured** | **Manufactured, Redwood** | **Rock, Manufactured** | **Manufactured** |
| **Hydraulic Loading** | **gpm/sq. ft** | **0.02-0.06** | **0.06-0.16** | **0.16-0.64** | **0.2-1.20** | **0.8-3.2** | **0.16-0.64** | **0.6-1.5** |
| **BOD Loading** | **lbs BOD/1000 cubic ft/day** | **5-25** | **15-30** | **30-60** | **30-100** | **100-500** | **60-120** | |
| **Depth** | **ft** | **6-8** | **6-8** | **3-6** | **10-40** | **15-40** | **6-8** | **<40** |
| **Recirculation Ratio** | | **0** | **0-1** | **1-2** | **1-2** | **1-4** | **0.5-2** | **0.5** |
| **Typical BOD Removal** | **%** | **80-90** | **50-70** | **65-85** | **65-80** | **40-65** | **85-95** | |

**4. Design Safety Factors. Trickling filters are affected by diurnal load conditions. The volume of media determined from either pilot plant studies or use of acceptable design equations shall be based upon the design peak hourly organic loading rate rather than the average rate. An alternative would be to provide flow equalization.**

*[1]***5**. Distribution.

A. Uniformity. The *[sewage]* **wastewater** may be distributed over the filter by rotary distributors or other suitable devices which will ensure uniform distribution to the surface area. At design average flow, the deviation from a calculated uniformly distributed volume per square foot ($m^2$) of the filter surface shall not exceed plus or minus ten percent (±10%) at any point. All hydraulic factors involving proper distribution of *[sewage]* **wastewater** on the filters shall be **carefully calculated and** submitted to the *[agency]* **Department as part of the Summary of Design required in 10 CSR 20-8.0110**.

B. Head requirements. For reaction type distributions, a minimum head of twenty-four inches (24") (61 cm) between low water level in siphon chamber and center of arms is required. Similar allowance in design shall be provided for added pumping head requirements where pumping to the reaction type distributor is used.

C. Clearance. A minimum clearance of six inches (6") (15 cm) between media and distributor arms shall be provided. Greater clearance is essential where icing may occur.

**D. Reverse reaction nozzles, hydraulic brakes or motor-driven distributor arms shall be provided for rotary distributors to ensure that the maximum speed recommended by the distributor manufacturer is not exceeded and to attain the desired media dosing rate.**

*[2. Dosing. Sewage may be applied to the filters by siphons, pumps or by gravity discharge from preceding treatment units when suitable flow characteristics have been developed. Application of the sewage shall be practically continuous. The piping system shall be designed for recirculation.]*

*[3]***6**. Piping system. The piping system including dosing equipment and distributor shall be designed to provide capacity for the peak hourly flow rate including recirculation*[required under paragraph (3)(E)5. of this rule.]* **as required to achieve the design efficiency.**

**7. Pretreatment. A trickling filter shall have upstream preliminary treatment units that:**

**A. Remove grit, debris, suspended solids, oil, and grease;**

**B. Have particles with a diameter greater than three millimeters (3mm); and**

**C. Control the release of hydrogen sulfide.**

**8. Freeboard. A freeboard of four feet (4') (1.2 m) or more should be provided for tall, manufactured media filters to maximize the containment of windblown spray.**

**9. Winter protection. Adequate protection such as covers in severe climate or wind breaks in moderate climates shall be provided to maintain operation and treatment efficiencies when climatic conditions are expected to result in problems due to cold temperatures.**

(C) Media.

**1. Unit Sizing. Required volumes of rock or slag media filters shall be based upon pilot testing with the particular wastewater or any of the various empirical design equations that have been verified through actual full scale experience.**

**A. Calculations shall be submitted, as part of the Summary of Design required in 10 CSR 20-8.0110.**

**B. Pilot testing is recommended to verify performance predictions based upon the various design equations, particularly when significant amounts of industrial wastes are present.**

**C. Expected performance of filters packed with manufactured media shall be determined from documented full scale experience at similar installation or through actual use of a pilot plant on-site**

*[1]***2**. Quality. The media may be crushed rock, slag or specially manufactured material. The media shall be durable, resistant to spalling or flaking and be relatively insoluble in *[sewage]* **wastewater**.

**A.** The top eighteen inches (18") (46 cm) shall have a loss by the twenty (20)-cycle, sodium sulfate soundness test of not more than ten percent (10%), as prescribed by the *ASCE Manual of Engineering Practice*, Number 13; the balance is to pass a ten (10)-cycle test using the same criteria.

**B.** Slag media shall be free from iron.

**C.** Manufactured media shall be resistant to ultraviolet degradation, disintegration, erosion, aging, all common acids and alkalies, organic compounds and fungus and biological attack.

**D.** Media shall be either structurally capable of supporting a man's weight or a suitable access walkway provided to allow for distributor maintenance.

*[2]***3**. Depth.

**A**. Rock and/or slag filter media shall have a minimum depth of five feet (5') (1.5 m) above the underdrains.

**B.** Manufactured filter media should have a minimum depth of ten feet (10') (3m) to provide adequate contact time with the wastewater.

**C**. Rock and/or slag filter media depths shall not exceed ten feet (10') (3m) and manufactured filter media depths shall not exceed thirty feet (30') (9.1m) except where special construction is justified through extensive pilot studies.

*[3]***4**. Size and grading of media.

A. Rock, slag and similar media. Rock, slag and similar media shall not contain more than five percent (5%) by weight of pieces whose longest dimension is three (3) times the least dimension. They shall be free from thin elongated and flat pieces, dust, clay, sand or fine material and shall conform to the following size and grading when mechanically graded over vibrating screen with square openings.

**1.** Passing 4 1/2-inch (4 1/2") screen (11.4 cm)—one hundred percent (100%) by weight.

**2.** Retained on 3-inch (3") screen (7.6 cm)—ninety-five to one hundred percent (95–100%) by weight.

**3.** Passing 2-inch (2") screen (5.1 cm)—0.2% by weight.

**4.** Passing 1-inch (1") screen (2.5 cm)—0.1% by weight.

**5. Maximum dimensions of stone--five inches**

**6. Minimum dimensions of stone--three inches**

B. Manufactured Media. Suitability will be evaluated on the basis of experience with installations handling similar wastes and loadings.

**1. Any synthetic media material must be used in accordance with all manufacturer's recommendations.**

**2. Synthetic media material may be considered innovative or nonconforming technology and may be subject to 10 CSR 20-8.140().**

**3. Suitability. The suitability of synthetic media material must be evaluated based on experience with an installation treating wastewater under similar hydraulic and organic loading conditions. The report must include a relevant case history involving the use of the synthetic media.**

**4. Durability. A synthetic media must be insoluble in wastewater and resistant to flaking, spalling, ultraviolet degradation, disintegration, erosion, aging, common acids and alkalis, organic compounds, and biological attack.**

**5. Structural Integrity.**

**A. A structural design must support the synthetic media, water flowing through or trapped in voids, and the maximum anticipated thickness of the wetted biofilm.**

**B. The synthetic media must support the weight of a person, unless a separate provision is made for maintenance access to the entire top of the trickling filter media and to the distributor.**

**6. Placing of Synthetic Media. Modular synthetic media must be installed with the edges matched as nearly as possible to provide consistent hydraulic conditions within the trickling filter.**

C. Handling and placing of media. Material delivered to the filter site shall be stored on wood planks or other approved clean hard surfaced areas. All material shall be rehandled at the filter site and no material shall be dumped directly into the filter.

**1.** Crushed rock, slag and similar media shall be washed and rescreened or forked at the filter site to remove all fines.

**2.** The material shall be placed by hand to a depth of twelve inches (12") (30 cm) above the tile underdrains and the remainder of material may be placed by means of belt conveyors or equally effective methods approved by the engineer.

**3.** All material shall be carefully placed so as not to damage the underdrains.

**4.** Manufactured media shall be handled and placed as approved by the engineer.

**5.** Trucks, tractors or other heavy equipment shall not be driven over the filter during or after construction.

(D) Underdrainage System.

1. Arrangement. Underdrains with semicircular inverts or equivalent should be provided and the underdrainage system shall cover the entire floor of the filter. Inlet openings into the underdrains shall have an unsubmerged gross combined area equal to at least fifteen percent (15%) of the surface area of the filter.
2. Hydraulic capacity *[and ventilation]*. The underdrains shall have a minimum slope of one percent (1%).

**A.** Effluent channels shall be designed to produce a minimum velocity of two feet (2') per second (0.61m/s) at average daily rate of application to the filter.

**B.** The underdrainage system, effluent channels and effluent pipe shall be designed to permit free passage of air.

**C.** The size of drains, channels and pipe should be so that not more than fifty percent (50%) of their cross section area will be submerged under the design peak hydraulic loading, including proposed or possible future or recirculated flows.

**D.** Consideration shall be given to the use of forced ventilation, particularly for covered filters and deep manufactured media filters.

3. Flushing. Provision should be made for flushing the underdrains. In small filters, use of a peripheral head channel with vertical vents is acceptable for flushing purposes. Inspection facilities should be provided.

*[(E) Special Features.*

*1. Flooding. Appropriate valves, sluice gates or other structures shall be provided so as to enable flooding of filters comprised of rock or slag media for filter fly control.*

*2. Freeboard. A freeboard of four feet (4') (1.2 m) or more should be provided for tall, manufactured media filters to maximize the containment of windblown spray.*

*3. Maintenance. All distribution de-vices, underdrains, channels and pipes shall be installed so that they may be properly maintained, flushed or drained.*

*4. Winter protection. Adequate protection such as covers in severe climate or wind breaks in moderate climates shall be provided to maintain operation and treatment efficiencies when climatic conditions are expected to result in problems due to cold temperatures.*

*5. Recirculation. The piping system shall be designed for recirculation as required to achieve the design efficiency. The recirculation rate shall be variable and subject to plant operator control.*

*6. Recirculation measurement. Devices shall be provided to permit measurement of the recirculation rate. Time lapse meters and pump head recording devices are acceptable for facilities treating less than one million gallons per day (1 mgd) (3785m$^3$/d).*

*(F) Rotary Distributor Seals. Mercury seals shall not be permitted. Ease of seal replacement shall be considered in the design to ensure continuity of operation.*

*(G) Multi-Stage Filters. The foregoing standards also apply to all multi-stage filters.*

*(H) Unit Sizing. Required volumes of rock or slag media filters shall be based upon pilot testing with the particular wastewater or any of the various empirical design equations that have been verified through actual full scale experience. Calculations must be submitted if pilot testing is not utilized. Pilot testing is recommended to verify performance predictions based upon the various design equations, particularly when significant amounts of industrial wastes are present. Expected performance of filters packed with manufactured media shall be determined from documented full scale experience at similar installation or through actual use of a pilot plant on-site.*

*(I) Design Safety Factors. Trickling filters are affected by diurnal load conditions. The volume of media determined from either pilot plant studies or use of acceptable design equations shall be based upon the design peak hourly organic loading rate rather than the average rate. An alternative would be to provide flow equalization.]*

**(E) Filter Dosing.**

1. **Suitable flow characteristics must be used for the application of wastewater to a filter by siphon, pump, or gravity discharge from preceding treatment unit.**
2. **A filter must be designed to control instantaneous dosing rates under both normal operating conditions and filter-flushing conditions.**
3. **The distributor speed and the recirculation rate must be adjusted for the dosing intensity as a compensatory measure under low-flow conditions. The following table provides design ranges of dosing intensity for normal usage periods and for flushing periods:**

| **Table: Trickling Filter Dosing Intensity Ranges (SK)** | | |
|---|---|---|
| **$BOD_5$ loading** ***kilogram (kg)/m³/day*** | **Design SK** ***mm/pass*** | **Flushing SK** ***mm/pass*** |
| **0.25** | **10-100** | **≥200** |
| **0.50** | **15-150** | **≥200** |
| **1.00** | **30-200** | **≥300** |
| **2.00** | **40-250** | **≥400** |
| **3.00** | **60-300** | **≥600** |
| **4.00** | **80-400** | **≥800** |

**4. A design may be based on instantaneous dosing intensity for rotary distributors using the equation:**

$$SK = \frac{(q + r) \times (1000mm/m)}{(a) \times (n) \times (60)}$$

**Where: SK = dosing intensity, millimeter (mm)/pass of an arm**
**Q = influent flow/filter top surface area, in cubic meters ($m^3$)/square meter ($m^2$)/hour**
**R = recycle flow/filter top surface area, $m^3/m^2$/hour**
**A = number of arms**
**N = revolutions per minute**

**(F) Ventilation**

**1. A ventilation fan and the associated controls shall withstand flooding of a filter without sustaining damage.**

**2. Forced Ventilation.**

**A. Forced ventilation is required for a trickling filter:**

**1. Designed for nitrification;**
**2. Designed with a media depth in excess of 6.0 feet; or**
**3. Any location where seasonal or diurnal temperatures do not provide sufficient difference between the ambient air and wastewater temperatures to sustain passive ventilation.**

**B. The design shall specify the minimum airflow for forced ventilation and optimized process performance, and include any calculation associated with the determination.**

**C. A down-flow forced ventilation system should include a provision for:**

**1. The removal of entrained droplets: or**
**2. The return of air containing entrained moisture to the top of a trickling filter; and**
**3. A reversible fan or other mechanism to reverse the airflow when a wide temperature difference between the ambient air and wastewater create strong updrafts.**

**D. Minimum design airflow rate for nitrifying trickling filter shall be the greater of:**

1. **Fifty pounds (50 lbs) of oxygen provided per pound of oxygen required at average organic loading, based on stoichiometry; or**
2. **Thirty pounds (30 lbs) of oxygen provided per pound of oxygen required at peak organic loading, based on stoichiometry.**
3. **The minimum required ventilating area for a synthetic media underdrain is the area recommended by the manufacturer, or using the following equation and the values in the aeration rate and loading factors table to determine the minimum airflow rate:**

$$MAFR = \frac{(R_A) \times (L) \times (P_F)}{1440 \min/day}$$

**Where: MAFR = Minimum airflow rate, scfm ; $R_A$ = Aeration rate, scf/lb, Table ; L = Loading rate, lb/day, Table ; $P_F$ = Loading peaking factor**

| Table: Aeration Rate and Loading Rate Factors | | | |
|---|---|---|---|
| **Filter Application** | | **Aeration rate** | **Loading Rate** |
| | **lb $BOD_5$/1000 cf/day** | **$R_A$ (scf/lb $BOD_5$)** | **L (lb $BOD_5$/1000 cf/day) Loading on the filter** |
| **Roughing Filter** | **75-200** | **1080** | **$BOD_5$** |
| **Secondary Treatment Filter** | **25-50** | **1200** | **$BOD_5$** |
| **Combined or Tertiary Filter** | | **2400** | **1.25 * $BOD_5$ + 4.6 * total Kjeldahl nitrogen (TKN)** |

**(G) Recirculation. The recirculation rate should be variable and subject to plant operator control.**

1. **Low Flow Conditions.**
   - **A. A design must include minimum recirculation during periods of low flow in order to ensure that the biological growth on the filter media remains active at all times.**
   - **B. A design must include the minimum recirculation in the evaluation of the efficiency of a filter, if it is part of a proposed specified continuous recirculation rate.**
   - **C. Minimum flow to the filters must equal to or greater than 1.0 mgd per acre of filter aerial surface and must keep the distribution nozzles properly operating.**
   - **D. The minimum flow rate for a design using hydraulically driven distributors must keep rotary distributors turning at the minimum design rotational velocity.**
   - **E. For a facility designed with a capacity equal to or greater than 0.1 mgd and recirculation for $BOD_5$ removal, the recirculation system must include variable speed pumps and a method of conveniently measuring the recycle flow rate. Time lapse meters and pump head recording devices are acceptable measurement devises for facilities treating less than one million gallons per day (1 mgd) (3785$m^3$/d).**
2. **Compensatory Recirculation.**

**A. A design must provide recirculation to supplement influent flow if design and flushing dosing intensities are not achieved solely by the control of distributor operation.**

**B. Controls for the distributor speed and recycle pumping rate must provide optimum dosing intensity under all anticipated influent flow conditions.**

**3. Maximum Recirculation Rate. A recirculation rate may exceed four times design flow if calculations to justify the higher rate are provided.**

**4. Configuration.**

**A. In a facility with influent that has constant organic loadings, a system should use direct recirculation of unsettled trickling filter effluent.**

**B. A design should ensure that the distributor nozzles can handle the recirculated sloughed biofilm.**

**C. In a facility with variable influent organic loadings, effluent shall recirculate from a final clarifier to either a primary clarifier or a trickling filter to equalize organic loading.**

**(H) Distribution Equipment.**

**1. A design shall include a rotary, horizontal, or traveling wastewater distribution system that distributes wastewater uniformly over the entire surface of a filter at the design and flushing dosing intensities.**

**2. A design should include filter distributors that operate properly at all anticipated flow rates.**

**3. A design shall not deviate from the design dosing intensity by more than 10%.**

**4. A new trickling filter or upgrade of an existing trickling filter should include electrically driven, variable speed a filter distributor to allow operation at optimum dosing intensity independent of recirculation pumping.**

**5. If an existing rectangular trickling filter is retrofitted with rotary distributors, any media that will not be fully wetted shall not be considered part of the required effective treatment area.**

**6. The center column of a rotary filter distributor shall have adequately sized overflow ports to prevent water from reaching the bearings in the center column.**

**7. A filter distributor shall include cleanout gates on the ends of the arms and an end spray nozzle to wet the edge of the media.**

**8. The filter walls should extend at least twelve inches (12.0”) above the top of the ends of the distributor arms.**

**9. The use of a mercury seal in a distributor of a trickling filter is prohibited. Ease of seal replacement shall be considered in the design to ensure continuity of operation**

**10. The minimum clearance between the top of the filter media and the distributing nozzles is six inches (6.0”).**

**11. Rotary distributors should capable of operating at speeds as low as one revolution per 30 minutes.**

**12. A trickling filter with a height or diameter that does not allow distributors to be removed and replaced by a crane shall provide jacking columns and pads at the distributor column.**

**(I) Maintenance. All distribution de-vices, underdrains, channels and pipes shall be installed so that they may be properly maintained, flushed or drained.**

**1. Cleaning and Sloughing.**

**A. A flow distribution device, an underdrain, a channel, and a pipe shall allow maintenance, flushing, and drainage.**

**B. A trickling system shall hydraulically accommodate the specified flushing hydraulic dosing intensity and must facilitate cleaning and rodding of the distributor arms.**

**C. A trickling filter system shall prevent recirculation of sloughed biomass in pieces larger than the distributor nozzle opening or the filter media voids.**

**2. Nuisance Organism Control. A trickling filter system shall control nuisance organisms by operation of trickling filters at proper design dosing intensities, with periodic flushing at higher dosing intensities.**

**A. Filter Flies. The structural and hydraulic design of a trickling filter should enable flooding of the trickling filter for fly control.**

**B. Snails. A trickling filter system must minimize areas where sludge may accumulate. The system must include a low-velocity, open channel between a trickling filter and final clarifier for manual removal of snails.**

**3. Corrosion Protection. A design must minimize corrosion and use corrosion-resistant materials for all equipment and construction of a trickling filter, including ventilation equipment and covers.**

**4. Flow Measurements. A trickling filter system shall include a means to measure the flow to a filter and the recirculation flow.**

**5. Odor Control. A trickling filter system should use ventilation with periodic flushing at a higher dosing intensity to minimize potential odor.**

**A. Covers.**

**1. A cover should allow access to the entire top of the filter media and to the distributor for maintenance and removal.**

**2. A covered trickling filter should have a forced ventilation system with a scrubber or an adsorption column for odor control.**

**3.Stripping. A trickling filter with high influent organic loading should have forced ventilation in a down-flow mode to minimize odor. Odorous off-gases may be:**

**A. recycled through a trickling filter;**

**B. used to ventilate a tertiary nitrifying trickling filter in an up-flow mode;**

**C. diffused into an aeration basin; or**

**D. treated separately for odor control using a scrubber or an adsorption column.**

**6. Final Clarifiers. The size of the final clarifiers for a facility with a trickling filter must allow for the required effluent total suspended solids removal at the maximum influent flow and the maximum recirculation with all pumps in operation.**

***[(4) Activated Sludge.***

*(A) General.*

*1. Applicability.*

*A. Biodegradable wastes. The activated sludge process and its various modifications may be used where sewage is amenable to biological treatment.*

*B. Operational requirement. This process requires close attention and competent operating supervision, including routine laboratory control. These requirements shall be considered when proposing this type of treatment.*

*C. Energy requirement. This process requires major energy usage to meet aeration demands. Energy costs and potential mandatory emergency public power reduction events in relation to critical water quality conditions must be carefully evaluated. Capability of energy usage phase down while still maintaining process viability, both under normal and emergency availability conditions, must be included in the activated sludge design.*

*2. Specific process selection. The activated sludge process and its several modifications may be employed to accomplish varied degrees of removal of suspended solids and reduction of carbonaceous and/or nitrogenous oxygen demand. Choice of the process most applicable will be influenced by the degree and consistency of treatment required, type of waste to be treated, proposed plant size, anticipated degree of operation and maintenance, and operating and capital costs. All designs shall provide for flexibility in operation. Plants over one (1) mgd (3785 $m^3$/d) shall be designed to facilitate easy conversion to various operation modes.*

*3. Winter protection. In severe climates, protection against freezing shall be provided to insure continuity of operation and performance.*

*(B) Pretreatment. Where primary settling tanks are not used, effective removal or exclusion of grit, debris, excessive oil or grease and comminution or screening of solids shall be accomplished prior to the activated sludge process. Where primary settling is used, provision shall be made for discharging raw sewage directly to the aeration tanks to facilitate plant start-up and operation during the initial stages of the plant's design life.*

*(C) Aeration.*

*1. Capacities and permissible loadings. The size of the aeration tank for any particular adaptation of the process shall be determined by full scale experience, plant pilot studies or rational calculations based mainly on food to microorganism ratio and mixed liquor suspended solids levels. Other factors such as size of treatment plant, diurnal load variations and degree of treatment required shall also be considered. In addition, temperature, pH and reactor dissolved oxygen shall be considered when designing for nitrification. Calculations should be submitted to justify the basis for design of aeration tank capacity. Calculations using values differing substantially from those in the accompanying table should reference actual operational plants. Mixed liquor suspended solids levels greater than five thousand (5000) mg/l may be allowed provided that adequate data is submitted that shows the aeration and clarification system is capable of supporting the levels. When process design calculations are not submitted, the aeration tank capacities and permissible loadings for the several adaptations of the processes shown in the following table shall be used. These values apply to plants receiving peak to average diurnal load ratios ranging from about two to one (2:1) to four to one (4:1). The utilization of flow equalization facilities to reduce the diurnal peak organic load may be considered by the agency as justification to approve organic loading rates that exceed those specified in the table.*

***Permissible Aeration Tank Capacities and Loadings***

*(NOTE: For proper use of this table, see paragraph (4)(C)1. of this rule.)*

| ***Aeration Tank Organic Loading-lb. $BOD_5$/1,000 $BOD_5$/lb. MLVSS/ MLSS**** | ***F/M Ratio-lb.*** |
|---|---|

| ***Process*** | ***cu. ft./day*** | ***day*** | ***mg/liter*** |
|---|---|---|---|
| *Step Aeration, Complete Mix, and Conventional* | *40* | *0.2–0.5* | *1000–3000* |
| *Contact Stabilization* | *50*** | *0.2–0.6* | *1000–3000* |
| *Extended Aeration and Oxidation-Ditches* | *15* | *0.05–0.1* | *3000–5000* |

**MLSS values are dependent upon the surface area provided for sedimentation and the rate of sludge return as well as the aeration process.*

***Total aeration capacity, includes both contact and reaeration capacities. Normally the contact zone equals thirty to thirty-five percent (30%–35%) of the total aeration capacity.*

*2. Arrangement of aeration tanks.*

*A. General tank configuration.*

*(I) Dimensions. The dimensions of each independent mixed liquor aeration tank or return sludge reaeration tank shall be so as to maintain effective mixing and utilization of air. Ordinarily, liquid depths should not be less than ten feet (10') (3 m) or more than thirty feet (30') (9 m) except in special design cases.*

*(II) Short-circuiting. For very small tanks or tanks with special configuration, the shape of the tank and the installation of aeration equipment should provide the positive control of short-circuiting through the tank.*

*B. Number of units. Total aeration tank volume required shall be divided among two (2) or more units, capable of independent operation, when required by the agency to meet applicable effluent limitations and reliability guidelines.*

*C. Inlets and outlets.*

*(I) Controls. Inlets and outlets for each aeration tank unit shall be suitably equipped with valves, gates, stop plates, weirs or other devices to permit controlling the flow to any unit and to maintain reasonably constant liquid level. The hydraulic properties of the system shall permit the maximum instantaneous hydraulic load to be carried with any single aeration tank unit out-of-service.*

*(II) Conduits. Channels and pipes carrying liquids with solids in suspension shall be designed to maintain self-cleansing velocities or shall be agitated to keep the solids in suspension at all rates of flow within the design limits. Adequate provisions should be made to drain segments of channels which are not being used due to alternate flow patterns.*

*D. Freeboard. All aeration tanks should have a freeboard of not less than eighteen inches (18") (46 cm). Additional freeboard or windbreak may be necessary to protect against freezing or wind blown spray.*

*3. Aeration equipment.*

*A. General. Oxygen requirements generally depend on maximum diurnal organic loading, degree of treatment and level of suspended solids concentration to be maintained in the aeration tank mixed liquor. Aeration equipment shall be capable of maintaining a minimum of two (2.0) mg/l of dissolved oxygen in the mixed liquor at all times and providing thorough mixing of the mixed liquor. In the absence of experimentally determined values, the design oxygen requirements for all activated sludge processes shall be 1.1 lbs. $0_2$/lb. peak $BOD_5$ applied to the aeration tanks (1.1 kg $0_2$/kg peak $BOD_5$) except the value of 1.8 shall be used for the extended aeration process. In the case of nitrification, the oxygen requirement for oxidizing ammonia must be added to the above requirement for carbonaceous $BOD_5$ removal. The nitrogen oxygen demand (NOD) shall be taken as 4.6 times the diurnal peak total kjeldahl nitrogen (TKN) content of the influent. In addition, the oxygen demands due to recycle flows—heat treatment supernatant, vacuum filtrate, elutriates, etc., must be considered due to the high concentration of $BOD_5$ and TKN associated with the flows. Careful consideration should be given to maximizing oxygen utilization per unit power input. Unless flow equalization is provided, the aeration system should be designed to match the diurnal organic load variation while economizing on power input.*

*B. Diffused air systems. The desire of the diffused air system to provide the oxygen requirements shall be done by either of the following two (2) methods.*

*(I) Having determined the oxygen requirements per subparagraph (4)(C)3.A. of this rule, air requirements for a diffused air system shall by use of any of the well known equations incorporate such factors as tank depth, alpha factor of waste, beta factor of waste, certified aeration device transfer efficiency, minimum aeration tank dissolved oxygen concentrations, critical wastewater temperature and altitude of plant. In the absence of experimentally determined alpha and beta factors, wastewater transfer efficiency shall be assumed to be fifty percent (50%) of clean water efficiency for plants treating primarily ninety percent (90%) or greater domestic sewage. Treatment plants where the waste contains higher percentages of industrial wastes shall use a correspondingly lower percentage of clean water efficiency and shall have calculations submitted to justify such a percentage.*

*(II) Normal air requirements for all activated sludge processes except extended aeration (assuming equipment capable of transmitting to the mixed liquor the amount of oxygen required in subparagraph (4)(C)3.A.) shall be considered to be fifteen hundred (1500) cu.ft. per pound of $BOD_5$ peak aeration tank loading (93.5 $m^3$/kg of $BOD_5$). For the extended-aeration process the value shall be two thousand (2000) cu. ft. (125 m).*

*(III) To the air requirements calculated in part (4)(C)3.B.(II) of this rule shall be added air required for channels, pumps, aerobic digesters or other air-use demand.*

*(IV) The specified capacity of blowers or air compressors, particularly centrifugal blowers, should take into account that the air intake temperature may reach forty degrees Celsius (40 °C) (one hundred four degrees Fahrenheit (104 °F)) or higher and the pressure may be less than normal. The specified capacity of the motor drive should also take into account that the intake air may be minus thirty degrees Celsius (-30 °C) (minus twenty-two degrees Fahrenheit (-22 °F)) or less and may require oversizing of the motor or a means of reducing the rate of air delivery to prevent overheating or damage to the motor.*

*(V) The blowers shall be so provided in multiple units, so arranged and in such capacities as to meet the maximum air demand with the single largest unit out-of-service. The design shall also provide for varying the volume of air delivered in proportion to the load demand of the plant. Aeration equipment shall be easily adjustable in increments and shall maintain solids suspension within these limits.*

*(VI) Diffuser systems shall be capable of providing for the diurnal peak oxygen demand or two hundred percent (200%) of the design average oxygen demand whichever is larger. The air diffusion piping and diffuser system shall be capable of delivering normal air requirements with minimal friction losses. Air piping systems should be designed such that total head loss from blower outlet (or silencer outlet where used) to the diffuser inlet does not exceed 0.5 pounds per square inch (psi) (0.04 kgf/cm$^2$) at average operating conditions. The spacing of diffusers should be in accordance with the oxygen requirements within the channel or tank, and should be designed to facilitate adjustment of their spacing without major revision to air header piping. All plants employing less than four (4) independent aeration tanks shall be designed to incorporate removable diffusers that can be serviced and/or replaced without de-watering the tank.*

*(VII) Individual assembly units of diffusers shall be equipped with control valves, preferably with indicator markings for throttling or for complete shutoff. Diffusers in any single assembly shall have substantially uniform pressure loss.*

*(VIII) Air filters shall be provided in numbers, arrangements and capacities to furnish at all times an air supply sufficiently free from dust to prevent damage to blowers and clogging of the diffuser system used.*

*C. Mechanical aeration systems.*

*(I) Oxygen transfer performance. The mechanism and drive unit shall be designed for the expected conditions in the aeration tank in terms of the power performance. Certified testing shall verify mechanical aerator performance.*

*(II) Design requirements. The design requirements of a mechanical aeration system shall accomplish the following: maintain a minimum of two (2.0) mg/l of dissolved oxygen in the mixed liquor at all times throughout the tank or basin; maintain all biological solids in suspension; meet maximum oxygen demand and maintain process performance with the largest unit out-of-service; and provide for varying the amount of oxygen transferred in proportion to the load demand on the plant.*

*(III) Winter protection. Due to high heat loss, the mechanism as well as subsequent treatment units shall be protected from freezing where extended cold weather conditions occur.*

*(D) Return Sludge Equipment.*

*1. Return sludge rate. The minimum permissible return sludge rate of withdrawal from the final settling tank is a function of the concentration of suspended solids in the mixed liquor entering it, the sludge volume index of these solids and the length of time these solids are retained in the settling tank. Since undue retention of solids in the final settling tanks may be deleterious to both the aeration and sedimentation phases of the activated sludge process, the rate of sludge return expressed as a percentage of the average design flow of sewage should generally be variable between the limits set forth as follows:*

| | ***Minimum*** | ***Maximum*** |
|---|---|---|
| *Standard Rate* | *15* | *75* |
| *Carbonaceous Stage of Separate Stage Nitrification* | *15* | *75* |
| *Step Aeration* | *15* | *75* |
| *Contact Stabilization* | *50* | *150* |
| *Extended Aeration* | *50* | *150* |

| | | |
|---|---|---|
| *Nitrification Stage of Separate Stage Nitrification* | *50* | *200* |

*The rate of sludge return shall be varied by means of variable speed motors, drives or times (small plants) to pump sludge at the rates mentioned in the previous table.*

*2. Return sludge pumps. If motor driven return sludge pumps are used, the maximum return sludge capacity shall be obtained with the largest pump out-of-service. A positive head should be provided on pump suctions. Pumps should have at least three-inch (3") (7.6 cm) suction and discharge openings. If air lifts are used for returning sludge from each settling tank hopper, no standby unit will be required provided the design of the air lifts are so as to facilitate their rapid and easy cleaning and provided other suitable standby measures are provided. Air lifts should be at least three inches (3") (7.6 cm) in diameter.*

*3. Return sludge piping. Discharge piping should be at least four inches (4") (10 cm) in diameter and should be designed to maintain a velocity of not less than two feet (2') per second (0.61 m/s) when return sludge facilities are operating at normal return sludge rates. Suitable devices for observing, sampling and controlling return activated sludge flow from each settling tank hopper shall be provided.*

*4. Waste sludge facilities. Waste sludge control facilities should have a maximum capacity of not less than twenty-five percent (25%) of the average rate of sewage flow and function satisfactorily at rates of 0.5 percent of average sewage flow or a minimum of ten (10) gallons per minute (0.63 l/s), whichever may be the larger. Means for observing, measuring, sampling and controlling waste activated sludge flow shall be provided. Waste sludge may be discharged to the concentration or thickening tank, primary settling tank, sludge digestion tank, vacuum filters or any practical combination of these units.*

*(E) Measuring Devices. Devices should be installed in all plants for indicating flow rates of raw sewage or primary effluent, return sludge and air to each tank unit. For plants designed for sewage flows of 1 mgd (3785 $m^3$/d) or more, these devices should totalize and record, as well as, indicate flows. Where the design provides for all return sludge to be mixed with the raw sewage (or primary effluent) at one (1) location, then the mixed liquor flow rate to each aeration unit should be measured.]*

(5) Rotating Biological Contactors.

(A) General.

1. Applicability. The rotating biological contactor (RBC) process may be used where *[sewage]* is amenable to biological treatment. The process may be used to accomplish carbonaceous and/or nitrogenous oxygen demand reductions. Design standards, operating data and experience for this process are not well established. Therefore, expected performance of RBCs shall be based upon experience to similar full scale installations or thoroughly documented pilot testing with the particular wastewater.

2. Winter protection. Wastewater temperature affects rotating contactor performance. Year round operation in colder climates requires that rotating contactors be covered to protect the biological growth from cold temperatures and the excessive loss of heat from the wastewater with the resulting loss of performance. *[Enclosures shall be constructed of a suitable corrosion-resistant material. Windows or simple louvered mechanisms which can be opened in the summer and closed in the winter shall be installed to provide adequate ventilation. To minimize condensation, the enclosure should be adequately insulated and/or heated.]*

(B) Required Pretreatment. RBCs must be preceded by effective *[settling tanks]* **pretreatment** equipped with scum and grease collecting devices *[unless substantial justification is submitted for other pretreatment devices]* which provide for effective removal of grit, debris and excessive oil or grease prior to the RBC units. Bar screening or comminution are not suitable as the sole means of pretreatment.

*[(C) Unit Sizing. Unit sizing shall be based on experience at similar full-scale installations or thoroughly documented pilot testing with the particular wastewater. In determining design loading rates, expressed in units of volume per day per unit area of media covered by biological growth, the following parameters must be considered: design flow rate and influent waste strength; percentage of $BOD_5$ to be removed; media arrangement including number of stages and unit area in each stage; rotational velocity of the media; retention time within the tank containing the media; and wastewater temperature; and the percentage of influent $BOD_5$ which is soluble. In addition to these parameters, loading rates for nitrification will depend upon influent TKN, pH and the allowable effluent ammonia nitrogen concentration.*

*(D) Design Safety Factor. Effluent concentrations of ammonia nitrogen from the RBC process designed for nitrification are affected by diurnal load variations. Therefore, it may be necessary to increase the design surface area proportional to the ammonia nitrogen diurnal peaking rates appropriately to meet effluent limitations. An alternative is to provide flow equalization sufficient to insure process performance within the required effluent limitations.]*

(C) Design.

1. **The facility plan and the summary of design required in 10 CSR 20-8.xxx shall include calculations, assumptions, pilot study data, or other information to justify the design and organic loading into the treatment plant. The facility plan shall include a RBC media area adjustment to compensate for the effects of the ratio of soluble BOD5 to total BOD5.**
2. **Provisions for positive and measurable flow control to individual contactors shall be provided. Piping shall permit each reactor to be operated in the parallel or series flow mode.**
3. **The design of the RBC shaft and media support structures shall assure protection from structural failure for the design life of the treatment works.**
4. **Unit sizing shall be based on experience at similar full-scale installations or thoroughly documented pilot testing with the particular wastewater. In determining design loading rates, expressed in units of volume per day per unit area of media covered by biological growth, the following parameters must be considered:**
   - **A. design flow rate and influent waste strength;**
   - **B. percentage of $BOD_5$ to be removed;**
   - **C. media arrangement including number of stages and unit area in each stage;**
   - **D. rotational velocity of the media;**
   - **E. retention time within the tank containing the media;**
   - **F. wastewater temperature; and**
   - **G. the percentage of influent $BOD_5$ which is soluble.**
   - **H. In addition to these parameters, loading rates for nitrification will depend upon influent TKN, pH and the allowable effluent ammonia nitrogen concentration.**
5. **The organic loading rate should be less than 1.6 pounds BOD5/day/1,000 square feet of media (8 g/m2/d) and shall not exceed *[6.0]* 3.0 pounds of BOD5 per day per 1,000 square feet of media in any stage.**
6. **An RBC system designed for a BOD5 removal and nitrification must have at least four stages in series, unless justification is provided for a lesser number using operational data from either a full-scale operating facility or pilot unit with an appropriate scale-up factor.**
7. **The first stage of the RBC system must include a means of spreading the influent flow evenly across the media.**
8. **The system must include flow equalization when the peak-to-design flow ratio is higher than 2.5 to 1.0 to prevent loss of fixed growth from the media.**

**9. The system shall be designed to maintain a minimum DO concentration 1.0 mg/L in all stages during the maximum organic loading rate.**

**10. A RBC system designed for nitrification shall have a maximum overall organic loading rate of 0.2 pounds of NH3-N/day/1,000 square feet of media (1g/m2/d) calculated for the fourth stage only, for wastewater temperature of 20 °C. At wastewater temperatures less than 20 °C, nitrification rates are reduced and designs must be appropriately adjusted to gain equivalent treatment.**

**11. A nitrifying RBC shall be designed to allow chemical addition if the influent pH is below 7.0.**

**12.The design must ensure that the RBC tank minimizes zone volumes that promote solids settling and includes tank drains to facilitate removal of any accumulated solids.**

**13. The design shall include provisions for chlorine or sodium hypochlorite addition upstream of the RBC system to control the growth of beggiatoa.**

**14. Provide at least 0.12 gal/ft2 of media for RBC tanks to maintain a hydraulic load of 2 gpd/ft2.**

**15. Provide a side water depth of 5 feet or submerge the media at least 40%. The clearance between the tank floor and the bottom of the rotating media shall be four to nine inches to maintain sufficient bottom velocities and prevent solids deposition in the tank.**

**16. Design consideration should be given to providing:**

**A. recirculation of secondary clarifier effluent;**

**B. positively controlled alternate flow distribution, such as step feed; and**

**C. combination air/mechanical drive systems.**

**(D)Aeration**

**1. Supplemental aeration shall be provided for the first stage of all mechanically driven RBC units with first stage soluble organic ($SBOD_5$) loadings greater than two pounds/1000 square foot of media surface.**

**2. The air flow shall be supplied by air headers and diffusers located beneath the rotating media at a rate of not less than 1.25 cfm/1000 square foot of media surface area.**

**3. The total design air flow rate may be provided by a single blower; however, two blowers, each providing 50% of the total air flow rate, are recommended.**

**4. The design shall provide the capability to vary the volume of air delivered to handle fluctuations in the treatment works loading.**

**5. The design of an air drive system shall provide the capability to vary the volume of air delivered to handle fluctuations in treatment works loading or to control shaft rotational speed and biofilm thickness.**

**A. Air delivered shall not be less than 2.5 cfm/1000 square foot of media surface area to meet treatment objectives. For operational flexibility and biofilm thickness control, blowers shall be provided in multiple units, so arranged and in such capacities to allow delivery of 150% of the treatment air requirement with the single largest blower unit out of service.**

**B. Provisions shall be made for independent air flow metering and control to each RBC shaft.**

**(E) Enclosures and Ventilation.**

**1. The process cover shall have working clearance of at least 30 inches above the RBC unit, unless the cover can be removed with on-site equipment.**

**2. Enclosures shall be constructed of a corrosion resistant material.**

**3. The RBC unit must include access doors on each end and observation ports with covers at 3.0 foot intervals along the RBC unit.**

**4. Windows or simple louvered mechanisms which can be opened in the summer and closed in the winter shall be installed to provide adequate ventilation.**
**5. To minimize condensation, the enclosure should be adequately insulated and/or heated**
**(F) Operations and Maintenance.**
**1. Provisions shall be made to allow access to the shaft bearings for routine maintenance and removal. In addition, hydraulic load cells (i.e., bearing lift or electronic strain gauges) should be provided to allow a determination of total shaft weight, which in turn can be used to estimate the depth of attached growth or the biofilm thickness. The drives used for shaft rotation may be provided through either mechanical gear reducers or special media features that utilize aeration as a turning force. A stand-by drive assembly shall be provided to ensure continuous operability.**

**A. Rotational velocity directly affects the level of wastewater treatment by providing contact, aeration, and mixing between the biomass and wastewater. The optimum rotational velocity will vary with the specific installations and is generally in the range of one to two revolutions per minute (RPM).**

**B. RBC mechanical drive assemblies should have the capability to vary shaft rotational speed for dissolved oxygen and biofilm thickness control. Drive systems and motors shall be provided with protective coatings suitable for high humidity environments**

(6)Activated Sludge.

(A) General.

1. Applicability.

A. Biodegradable wastes. The activated sludge process and its various modifications may be used where sewage is amenable to biological treatment **and the biological solids are separated from the treated water. It is a suspended growth type process that relies on secondary clarification for removal of effluent suspended solids while producing a concentrated return activated sludge flow.**

B. Operational requirement. This process requires close attention and competent operating supervision, including routine laboratory control **for monitoring and process control**. These requirements shall be considered when proposing this type of treatment.

C. Energy requirement. This process requires major energy usage to meet aeration demands. Energy costs and potential mandatory emergency public power reduction events in relation to critical water quality conditions must be carefully evaluated. Capability of energy usage phase down while still maintaining process viability, both under normal and emergency availability conditions, must be included in the activated sludge design.

2. Specific process selection. The activated sludge process and its several modifications may be employed to accomplish varied degrees of removal of suspended solids and reduction of carbonaceous and/or nitrogenous oxygen demand. Choice of the process most applicable will be influenced by the degree and consistency of treatment required, type of waste to be treated, proposed plant size, anticipated degree of operation and maintenance, and operating and capital costs. All designs shall provide for flexibility in operation. Plants over one (1) mgd (3785 $m^3$/d) shall be designed to facilitate easy conversion to various operation modes.

3. Winter protection. In severe climates, protection against freezing shall be provided to insure continuity of operation and performance.

(B) Pretreatment. Where primary settling tanks are not used, effective removal or exclusion of grit, debris, excessive oil or grease and comminution or screening of solids shall be accomplished prior to the activated sludge process. **Screening devices with clear openings of 1/4 inch (6 mm) or less shall be provided.** Where primary settling is used, provision shall be made for discharging raw sewage directly to the aeration tanks to facilitate plant start-up and operation during the initial stages of the plant's design life.

(C) *[Aeration]* Design.

1. Capacities and permissible loadings. The size of the aeration tank for any particular adaptation of the process shall be determined by full scale experience, plant pilot studies or rational calculations based mainly on food to microorganism **(F/M)** ratio and mixed liquor suspended solids levels. Other factors such as size of treatment plant, diurnal load variations and degree of treatment required shall also be considered. In addition, temperature, pH and reactor dissolved oxygen shall be considered when designing for nitrification.

2. Calculations *[should]* **shall** be submitted in the **summary of design** to justify the basis for design of aeration tank capacity. Calculations using values differing substantially from those in the accompanying table should reference actual operational plants. Mixed liquor suspended solids levels greater than five thousand (5000) mg/l may be allowed provided that adequate data is submitted that shows the aeration and clarification system is capable of supporting the levels.

3. When process design calculations are not submitted, the aeration tank capacities and permissible loadings for the several adaptations of the processes shown in the following table shall be used. These values apply to plants receiving peak to average diurnal load ratios ranging from about two to one (2:1) to four to one (4:1). The utilization of flow equalization facilities to reduce the diurnal peak organic load may be considered by the agency as justification to approve organic loading rates that exceed those specified in the table.

**Permissible Aeration Tank Capacities and Loadings**

*[(NOTE: For proper use of this table, see paragraph (4)(C)1. of this rule.)*

| ***Process*** | ***Aeration Tank Organic Loading-lb. $BOD_5$/1,000 cu. ft./day*** | ***F/M Ratio-lb. $BOD_5$/lb. MLVSS/ day*** | ***MLSS* mg/liter*** |
|---|---|---|---|
| *Step Aeration, Complete Mix, and Conventional* | *40* | *0.2–0.5* | *1000–3000* |
| *Contact Stabilization* | *50*** | *0.2–0.6* | *1000–3000* |
| *Extended Aeration and Oxidation-Ditches* | *15* | *0.05–0.1* | *3000–5000* |

**MLSS values are dependent upon the surface area provided for sedimentation and the rate of sludge return as well as the aeration process.*
***Total aeration capacity, includes both contact and reaeration capacities. Normally the contact zone equals thirty to thirty-five percent (30%–35%) of the total aeration capacity.]*

| Process Modification | SRT, d | F:M, lb $BOD_5$ applied/d/lb MLVSS | Volumetric loading, lb $BOD_5$/d/1000 cf | MLSS, mg/L | V/Q, h | $Q_r$/Q (Q=forward flow) |
|---|---|---|---|---|---|---|
| Conventional | 5-15 | 0.2-0.4 | 20-40 | 1,500-3,000 | 4-8 | 0.25-0.75 |
| Complete-mix | 5-15 | 0.2-0.6 | 50-120 | 2,500-4,000 | 3-5 | 0.25-1.0 |
| Step feed | 5-15 | 0.2-0.4 | 40-60 | 2,000-3,500 | 3-5 | 0.25-0.75 |
| Modified aeration | 0.2-0.5 | 1.5-5.0 | 75-150 | 200-1,000 | 1.5-3 | 0.05-0.25 |
| Contact stabilization | 5-15 | 0.2-0.6 | 60-75 | (1,000-3,000)[b] (4,000-10,000)[c] | (0.5-1.0)[b] (3-6)[c] | 0.5-1.50 |
| Extended aeration | 20-30 | 0.05-0.15 | 10-25 | 3,000-6,000 | 18-36 | 0.5-1.50 |
| High-rate aeration | 5-10 | 0.4-1.5 | 100-1,000 | 4,000-10,000 | 2-4 | 1.0-5.0 |
| Kraus process | 5-15 | 0.3-0.8 | 40-100 | 2,000-3,000 | 4-8 | 0.5-1.0 |
| High-purity oxygen | 3-10 | 0.25-1.0 | 100-200 | 2,000-5,000 | 1-3 | 0.25-0.5 |
| Oxidation ditch | 10-30 | 0.05-0.3 | 5-30 | 3,000-6,000 | 8-36 | 0.75-1.50 |
| Sequencing batch reactor | N/A | 0.05-0.3 | 5-15 | 1,500-5,000[e] | 12-50 | N/A |
| Single-stage nitrification | 8-20 | 0.10-0.25 (0.02-0.15)[d] | 5-20 | 2,000-3,500 | 6-15 | 0.50-1.50 |
| Separate stage nitrification | 15-100 | 0.050-0.2 (0.04-0.15)[d] | 3-9 | 2,000-3,500 | 3-6 | 0.50-2.00 |

**Notes:**

**a: Process modifications are described in Table 14.2 of WEF MOP 8 and Table 8-15 of Metcalf & Eddy 2003, *Wastewater Engineering: Treatment and Reuse*, 4th Edition. SRT = solids retention time, d = days, F:M = food to microorganism ratio, MLVSS = mixed liquor volatile suspended solids, cf = cubic feet, V = aeration volume, Q = forward flow rate, h = hours, $Q_r$ = return activated sludge (RAS) flow**

**b: Contact unit**

**c: Solids stabilization unit**

**d: TKN/MLVSS**

**e: MLSS varies depending on the portion of the operating cycle.**
**Source: WEF, MOP 8, *Design of Municipal Wastewater Treatment Plants*, 2010, Table 14.3.**

**4. The design must include methods to measure (e.g., DO, ammonia, pressure, air flow) and adjust the aeration supply and distribution to the aeration tank (e.g., valves).**

**5. Basin lining. Line earthen aeration basins with concrete, asphalt or equivalent material below the maximum water elevation. Do not use plastic liners in aeration tanks.**

*[2]***6**. Arrangement of aeration tanks.

A. General tank configuration.

(I) Dimensions. The dimensions of each independent mixed liquor aeration tank or return sludge reaeration tank shall be so as to maintain effective mixing and utilization of air. Ordinarily, liquid depths should not be less than ten feet (10') (3 m) or more than thirty feet (30') (9 m) except in special design cases. **Horizontally mixed aeration tanks shall have a depth of not less than 5.5 feet (1.7 m).**

(II) Short-circuiting. For very small tanks or tanks with special configuration, the shape of the tank and the installation of aeration equipment should provide the positive control of short-circuiting through the tank.

B. Number of units. Total aeration tank volume required shall be divided among two (2) or more units, capable of independent operation, when required by the agency to meet applicable effluent limitations and reliability guidelines.

C. Inlets and outlets.

(I) Controls. Inlets and outlets for each aeration tank unit shall be suitably equipped with valves, gates, stop plates, weirs or other devices to permit controlling the flow to any unit and to maintain reasonably constant liquid level. **The effluent weir for a horizontally mixed aeration tank system shall be easily adjustable by mechanical means and shall be sized based on the design peak instantaneous flow plus the maximum return sludge flow.** The hydraulic properties of the system shall permit the maximum instantaneous hydraulic load to be carried with any single aeration tank unit out-of-service.

(II) Conduits. Channels and pipes carrying liquids with solids in suspension shall be designed to maintain self-cleansing velocities or shall be agitated to keep the solids in suspension at all rates of flow within the design limits. Adequate provisions should be made to drain segments of channels which are not being used due to alternate flow patterns.

D. Freeboard. All aeration tanks should have a freeboard of not less than eighteen inches (18") (46 cm). **However, if a mechanical surface aerator is used, the freeboard should be not less than 3 feet (0.9 m) to protect against windblown spray freezing on walkways, etc**. Additional freeboard or windbreak may be necessary to protect against freezing or wind blown spray.

(D) Aeration equipment.

1. General. Oxygen requirements generally depend on maximum diurnal organic loading, degree of treatment and level of suspended solids concentration to be maintained in the aeration tank mixed liquor. Aeration equipment shall be capable of maintaining a minimum of two (2.0) mg/l of dissolved oxygen in the mixed liquor at all times and providing thorough mixing of the mixed liquor. **This criterion does not apply to anaerobic zones specifically designed for phosphorus removal or anoxic zones used as selectors or for nitrate removal.**

2. In the absence of experimentally determined values, the design oxygen requirements for all activated sludge processes shall *[be 1.1 lbs. $0_2$/lb. peak $BOD_5$ applied to the aeration tanks (1.1 kg $0_2$/kg peak $BOD_5$) except the value of 1.8 shall be used for the extended aeration process.]* use the minimum oxygen requirements for activated sludge processes, below:

**Minimum Oxygen Requirements for Activated Sludge Processes**

| Process | Oxygen Requirement |
|---|---|
| **Oxygen requirement for carbonaceous BOD (activated sludge treatment systems with SRT 5 to <20 days, pounds (lbs) $O_2$/lb BOD)** | **0.9-1.3[a]** |
| **Oxygen requirement for carbonaceous BOD (activated sludge treatment systems with SRT ≥20 days, lbs $O_2$/lb BOD)** | **1.5** |
| **Nitrogenous oxygen demand (lbs $O_2$/lb TKN)** | **4.6** |
| **Oxygen credit for denitrification (lbs $O_2$/lb N)** | **2.86[b]** |

**A**
**Design must justify selection with design SRT. In absence of case specific justification, design must use 1.2 lbs $O_2$/lb BOD.**
**b Use of oxygen credits from denitrification must be justified based on the specific process design (e.g., anoxic zone location, supplemental carbon, recycle, seasonal operation) to assure denitrification will occur.**

**3**. *[In the case of nitrification, the oxygen requirement for oxidizing ammonia must be added to the above requirement for carbonaceous $BOD_5$ removal. The nitrogen oxygen demand (NOD) shall be taken as 4.6 times the diurnal peak total kjeldahl nitrogen (TKN) content of the influent.]* In addition, the oxygen demands due to recycle flows—heat treatment supernatant, vacuum filtrate, elutriates, etc., must be considered due to the high concentration of $BOD_5$ and TKN associated with the flows.

**4.** Careful consideration should be given to maximizing oxygen utilization per unit power input. Unless flow equalization is provided, the aeration system should be designed to match the diurnal organic load variation while economizing on power input.

**5. The aeration system shall provide sufficient mixing to maintain suspension of MLSS under any flow condition unless a means for separate mixing is included. Minimum air mixing requirements are identified below. If the aeration system design deviates from these criteria, the summary of design must include justification that demonstrates adequate mixing is still provided.**

**A. Fine bubble, full-floor coverage: 0.12 scfm per square foot of tank area.**
**B. Spiral roll: 20 scfm per 1,000 cubic feet of tank volume.**
**C. Mechanical aeration: justified by type of mechanical aerator and tank geometry or in absence of this information, use 0.6 horsepower per 1,000 cubic feet of tank volume.**
**D. Coarse bubble: greater than or equal to 20 scfm/1,000 cubic feet of tank volume.**
**E. Horizontally mixed aeration tank system: maintain an average velocity of 1 fps.**

**6. The summary of design must include the design basis for determining the size of the aeration system, including supporting calculations. The following factors must be provided in the aeration system and blower design:**

**A. Flows (maximum month);**
**B. BOD and TKN maximum design loadings;**
**C. Anticipated effluent quality;**
**D. Standard oxygen transfer efficiency of system provided;**
**E. Actual transfer efficiency;**
**F. Alpha and beta factors;**
**G. Correction factors of oxygen saturation for plant altitude and diffuser submergence;**
**H. Design DO concentration.**
**I. Maximum and minimum ambient temperature.**
**J. Minimum, maximum, and average wastewater temperature;**
**K. Ambient pressure at site location;**
**L. Aerobic and total SRT, MLSS concentration;**
**M. Diffused air system, type of diffusers;**
**N. Minimum equipment rated capacity, number of units, and**
**O. Anticipated seasonal Sludge Volume Index (SVI) values.**

**7. Blowers and Air Compressors.**

**A. Blowers and air compressors must have sufficient capacity to provide the required aeration rate for biological treatment and the air requirements of any supplemental unit (i.e., together "process air") with the largest single unit out of service.**

**B. The summary of design must include blower or compressor calculations that show the actual air requirements for the expected temperature range, including both summer and winter conditions, and the impact of the actual site elevation on the air supply.**

**C. Blower capacity must be based on the air volume required on the expected summer conditions. The size of motors for compressors must be based on summer air flow rates and the winter temperature (or other means provided to control mass air flow rate and prevent motor overload).**

**D. Blower and compressor units must restart automatically after a power outage or the design must include a telemetry system or an auto-dialer with battery backup to notify an operator of any outage.**

*[B.]* **(E)** Diffused air systems. The desire of the diffused air system to provide the oxygen requirements shall be done by either of the following two (2) methods. **A diffused air system must have methods to provide an adjustable air supply to meet the variable load and changing process conditions (e.g., sufficient turndown, multiple compressors, valves).**

*[(I)]*1. Having determined the oxygen requirements per subparagraph (4)(C)3.A. of this rule, air requirements for a diffused air system shall by use of any of the well known equations incorporate such factors *[as tank depth, alpha factor of waste, beta factor of waste, certified aeration device transfer efficiency,minimum aeration tank dissolved oxygen concentrations, critical wastewater temperature, and altitude of plant. ]* **identified in subpart (D)6 of this rule.**

**2.** In the absence of experimentally determined alpha and beta factors, wastewater transfer efficiency shall be assumed to be fifty percent (50%) of clean water efficiency for plants treating primarily ninety percent (90%) or greater domestic sewage. Treatment plants where the waste contains higher percentages of industrial wastes shall use a correspondingly lower percentage of clean water efficiency and shall have calculations submitted to justify such a percentage.

*[(II)]* **3**. Normal air requirements for all activated sludge processes except extended aeration (assuming equipment capable of transmitting to the mixed liquor the amount of oxygen required in subparagraph (4)(C)3.A.) shall be considered to be fifteen hundred (1500) cu.ft. per pound of $BOD_5$ peak aeration tank loading (93.5 $m^3$/kg of $BOD_5$). For the extended-aeration process the value shall be *[two thousand (2000) cu. ft. (125 m)]* **two thousand fifty (2050) cubic feet per pound of $BOD_5$ (128 $m^3$/kg of $BOD_5$.**

*[(III)]***4**. To the air requirements calculated in part (4)(C)3.B.(II) of this rule shall be added air required for channels, pumps, aerobic digesters or other air-use demand.

*[(IV)]***5**. The specified capacity of blowers or air compressors, particularly centrifugal blowers, should take into account that the air intake temperature may reach forty degrees Celsius (40 °C) (one hundred four degrees Fahrenheit (104 °F)) or higher and the pressure may be less than normal. The specified capacity of the motor drive should also take into account that the intake air may be minus thirty degrees Celsius (-30 °C) (minus twenty-two degrees Fahrenheit (-22 °F)) or less and may require oversizing of the motor or a means of reducing the rate of air delivery to prevent overheating or damage to the motor.

*[(V)]***6.** The blowers shall be so provided in multiple units, so arranged and in such capacities as to meet the maximum air demand with the single largest unit out-of-service. The design shall also provide for varying the volume of air delivered in proportion to the load demand of the plant. Aeration equipment shall be easily adjustable in increments and shall maintain solids suspension within these limits.

*[(VI)]* **7.** Diffuser systems shall be capable of providing for the diurnal peak oxygen demand or two hundred percent (200%) of the design average oxygen demand whichever is larger.

**A.** The air diffusion piping and diffuser system shall be capable of delivering normal air requirements with minimal friction losses.

**B.** Air piping systems should be designed such that total head loss from blower outlet (or silencer outlet where used) to the diffuser inlet does not exceed 0.5 pounds per square inch (psi) (0.04 $kgf/cm^2$) at average operating conditions.

**C.** The spacing of diffusers should be in accordance with the oxygen requirements within the channel or tank, and should be designed to facilitate adjustment of their spacing without major revision to air header piping.

**D.** All plants employing less than four (4) independent aeration tanks shall be designed to incorporate removable diffusers that can be serviced and/or replaced without de-watering the tank.

*[(VII)]***8.** Individual assembly units of diffusers shall be equipped with control valves, preferably with indicator markings for throttling or for complete shutoff. Diffusers in any single assembly shall have substantially uniform pressure loss.
*[(VIII)]* **9**. Air filters shall be provided in numbers, arrangements and capacities to furnish at all times an air supply sufficiently free from dust to prevent damage to blowers and clogging of the diffuser system used.

**10. A submerged depth for a diffuser shall be equal to or greater than nine feet (9.0').**

**11. The summary of design must identify the basis for the diffuser design (e.g., what diffuser, how arranged) using the specific diffuser capabilities and oxygen transfer rates. The design spacing and arrangement of diffusers must be consistent with process oxygenation requirements throughout the tank and expected process operating modes. If alternate operating modes such as plug flow and step feed are provided, the summary of design must indicate how the diffuser layout is arranged so as to accommodate each mode.**

*[C.]* (F) Mechanical aeration systems.
*[(I)]*1. Oxygen transfer performance. The mechanism and drive unit shall be designed for the expected conditions in the aeration tank in terms of the power performance. Certified testing shall verify mechanical aerator performance. **In the absence of specific design information, the oxygen requirements shall be calculated using a transfer rate not to exceed 2 pounds of oxygen per horsepower per hour [1.22 kg $O_2$/(kW·h)] in clean water under standard test conditions. Design transfer efficiencies shall be included in the specifications.**
*[(II)]*2. Design requirements. The design requirements of a mechanical aeration system shall accomplish the following:

**A.** Maintain a minimum of two (2.0) mg/l of dissolved oxygen in the mixed liquor at all times throughout the tank or basin;
**B.** Mmaintain all biological solids in suspension;
**C. Mechanical aeration systems with channel or basin layout must have a minimum 0.75 horsepower per thousand cubic feet of aeration basin volume;**
**D. Each basin must include a minimum of two mechanical aeration devices;**
**E.** Meet maximum oxygen demand and maintain process performance with the largest unit out-of-service; *[and]*
**F.** Provide for varying the amount of oxygen transferred in proportion to the load demand on the plant;
**G.** Allow for motors, gear housing, bearings, grease fittings, etc., to be easily accessible and protected from inundation and spray as necessary for proper functioning of the unit; and
**H. The mechanical aeration device shall automatically restart after a power outage, or an alarm notification system (e.g., telemetry system with battery backup or an autodialer with battery backup) must notify a facility operator or owner.**

*[(III)]* 3. Winter protection. *[Due to high heat loss, the mechanism as well as subsequent treatment units shall be protected from freezing where extended cold weather conditions occur.*] **Where extended cold weather conditions occur, the aerator mechanism and associated structure shall be protected from freezing due to splashing and spray. Due to high heat loss, subsequent treatment units shall be protected from freezing.**

**(G) High purity oxygen. The following additional requirements apply to activated sludge systems which utilize high purity oxygen for aeration.**

**1. The design of activated sludge processes utilizing pure oxygen aeration shall provide for covered and compartmentalized reactors to provide a series of stages for biological growth. Sampling ports shall be provided for each compartment of the biological**

**reactors. An enclosed air-oxygen exhaust system shall be provided to collect and vent the reactor off-gases.**

**2. Mixing equipment shall be sufficient to maintain solids in suspension. Normally, the power input should be 0.5 to 1.3 horsepower per 10 cubic feet of aerator volume. The design basis for determining mixing requirements shall be submitted. Provisions shall be included for rapid removal or cleaning of the mixers.**

**3. The high purity oxygen storage and generation facilities and piping shall be remotely located from areas where flammable or explosive substances may be present. Warning signs shall be posted in the area of the oxygen storage and generation facilities. The covered aeration basins should be equipped with explosive atmosphere monitors and alarms in accordance with applicable state and federal regulations. An influent hydrocarbon monitor shall be included at the headworks to initiate operation of purge air blowers to vent reactor oxygen when explosive mixtures could occur.**

**4. At least two sources of oxygen shall be provided. On-site storage of oxygen for emergencies and peak demands is required. Storage of oxygen shall be determined by engineering analysis of the availability and delivery of oxygen to the treatment works site.**

**(H) Nitrification. The following requirements apply to activated sludge treatment works designed to provide nitrification.**

**1. The design shall ensure that an adequate nitrifying bacteria population can be maintained during the required time period (i.e., seasonal or year-round) without excessive reactor biomass (MLSS). This requires**

**A.A longer detention time;**

**B. A longer mean cell residence time (MCRT) with a relatively high ratio of the amount of biomass in the process compared to the rate of loss or wastage of biomass; and**

**C. A lower organic loading rate than that required for carbonaceous organic removal alone.**

**2. The design for processes other than the extended aeration modification shall be based on satisfactory process performance obtained at full scale or pilot scale facilities. Performance data and information from such facilities shall be included with the design data submittal and shall particularly address temperature and pH dependence of the nitrification process.**

**3. Flow equalization or other proven methods to eliminate the likelihood of loss of biomass or activated sludge washout shall be provided for sewage treatment works subject to infiltration/inflow rates which could be expected to result in periodic biomass or activated sludge nitrifier washout.**

**4. Feed equipment for the addition of chemicals to maintain a minimum alkalinity of fifty milligrams per liter (50 mg/L) in the aeration basin contents (mixed liquor) shall be provided when necessary, based on the characteristics of the influent wastewater. Approximately 7.2 pounds of alkalinity will be destroyed per pound of ammonia nitrogen oxidized.**

*([D] I*) Return Sludge Equipment.

1. Return sludge rate. The minimum permissible return sludge rate of withdrawal from the final settling tank is a function of the concentration of suspended solids in the mixed liquor entering it, the sludge volume index of these solids and the length of time these solids are retained in the settling tank. Since undue retention of solids in the final settling tanks may be deleterious to both the aeration and sedimentation phases of the activated sludge process, the rate of sludge return expressed as a percentage of the average design flow of sewage should generally be variable between the limits set forth as follows:

| | ***[Minimum*** | ***Maximum*** |
|---|---|---|
| *Standard Rate* | *15* | *75* |
| *Carbonaceous Stage of Separate Stage Nitrification* | *15* | *75* |
| *Step Aeration* | *15* | *75* |
| *Contact Stabilization* | *50* | *150* |
| *Extended Aeration* | *50* | *150* |
| *Nitrification Stage of Separate Stage Nitrification* | *50* | *200]* |

| | Minimum | Maximum |
|---|---|---|
| Standard Rate | 15% | 75% |
| Carbonaceous Stages of Separate Stage Nitrification | 15% | 75% |
| Step Aeration | 15% | 75% |
| Extended Aeration | 50% | 150% |
| Nitrification Stage of Separate Stage Nitrification | 50% | 200% |

The rate of sludge return shall be varied by means of variable speed motors, drives or times (small plants) to pump sludge at the rates mentioned in the previous table.

2. Return sludge pumps. If motor driven return sludge pumps are used, the maximum return sludge capacity shall be obtained with the largest pump out-of-service. A positive head should be provided on pump suctions. Pumps should have at least three-inch (3") (7.6 cm) suction and discharge openings. If air lifts are used for returning sludge from each settling tank hopper, no standby unit will be required provided the design of the air lifts are so as to facilitate their rapid and easy cleaning and provided other suitable standby measures are provided. Air lifts should be at least three inches (3") (7.6 cm) in diameter.

3. Return sludge piping. Discharge piping should be at least four inches (4") (10 cm) in diameter and should be designed to maintain a velocity of not less than two feet (2') per second (0.61 m/s) when return sludge facilities are operating at normal return sludge rates. Suitable devices for observing, sampling and controlling return activated sludge flow from each settling tank hopper shall be provided.

4. Waste sludge facilities. Waste sludge control facilities should have a maximum capacity of not less than twenty-five percent (25%) of the average rate of sewage flow and function satisfactorily at rates of 0.5 percent of average sewage flow or a minimum of ten (10) gallons per minute (0.63 l/s), whichever may be the larger. Means for observing, measuring, sampling and controlling waste activated sludge flow shall be provided. Waste sludge may be discharged to the concentration or thickening tank, primary settling tank, sludge digestion tank, vacuum filters or any practical combination of these units.

(J) Operations and Maintenance

1. Measuring Devices. Devices should be installed in all plants for indicating flow rates of raw sewage or primary effluent, return sludge and air to each tank unit. For plants designed for sewage flows of 1 mgd (3785 $m^3$/d) or more, these devices should totalize and record, as well as, indicate flows. Where the design provides for all return sludge to be mixed with the raw sewage (or primary effluent) at one (1) location, then the mixed liquor flow rate to each aeration unit should be measured.

**(7) Oxidation Ditches. An oxidation ditch process typically employs an extended aeration type of activated sludge process with a single channel or multiple interconnected concentric channels used as an aeration basin with a detention volume. The geometry of the channels can vary; however, the oval is the most common configuration.**

**(A) General.**

**1. For design flows up to 100,000 gpd, a single oxidation ditch should be sufficient for secondary treatment of discharges, if provided with external duplex clarifiers. For design flows greater than 100,000 gpd, or for treatment works permitted with effluent limits less than secondary or nutrient removal requirements, duplicate reactors and clarifiers shall be provided.**

**2. Pretreatment. Bar screens and grit removal facilities are required. Primary settling is not necessary except for high strength waste.**

**(B) Design.**

**1. The multiple concentric channel basin can have any number of interconnected channels. This channel design scheme provides some process flexibility, since with minor modifications it can be changed to other activated sludge process modes.**

**2.The volume of the oxidation ditch shall provide 18 to 24 hours hydraulic detention time at average dry weather flow.**

**3. Influent wastewater and returned sludge immediately upstream of the rotor that is farthest from the effluent control weir.**

**3. Organic loading shall be less than 15 pounds BOD per 1,000 ft3/day.**

**4. The depth of the oxidation ditch shall be at least four feet (4”).**

**5. Minimum sidewater depth shall be eight feet (8”)( m).**

**6. Freeboard shall be at least one foot (1”) at maximum water depths.**

**7. Oxidation ditches may also be operated in alternating modes through on/off operation of aeration/mixing devices with intermittent changes in flow rates or direction. Influent wastewater can be diverted through one or more multiple reactors in which different operational phases (anoxic, aerobic, etc.) may occur. Effluent clarification may be accomplished within the reactor or within a separate clarifier.**

**8.Automatically controlled weirs shall be used to regulate flow direction and alternating operation of aeration/mixing equipment controls the operating mode. As with either**

**standard continuous flow, or batch-type processes, the design duration of each operating phase is critical to performance reliability.**

**9. If only one train is provided, the design must include provisions for taking this train out of service for maintenance or during an upset.**

**10. Two complete rotor units should be installed. Design the system so a single rotor can provide the average design oxygen demand and minimum velocity of 1 fps throughout the basin.**

**11. Rotors shall be placed before a long, straight ditch section.**

**12. The design shall provide a method to control rotor submergence.**

**(C) Aeration. Since oxidation ditches are considered a variation of the extended aeration modification of the activated sludge process, the requirements set forth in subsection (6) of this rule are applicable except as follows:**

**1. The mixing system shall be capable of maintaining a minimum velocity throughout the oxidation ditch cross-section of 1.0 fps at maximum design depth and solids concentration. For designs utilizing in-channel suspended solids removal the mixing system shall provide for all necessary variations in flow velocity to achieve adequate separation of suspended solids. Calculations and certified performance data for the mixing system shall be submitted to substantiate the adequacy of the proposed design.**

**2. Designs based on anoxic operation shall provide mixing and aeration system capacity for aerobic operation with adequate turndown capability to operate in the anoxic mode. Flexibility to allow for operation in the anoxic mode should be considered for all designs.**

**3. Designs should provide for variation in the oxygen supply independent of the mixing function.**

**4. The outlet from the oxidation ditch shall be separated from the inlet in such a manner as to prevent discharging of partially treated effluent.**

**5. Intra-channel clarifiers may be utilized if conventional settling rates are maintained and sludge handling, treatment and management provisions are satisfactorily addressed.**

**6. A minimum of two mixers/aerators per ditch must be provided to maintain horizontal mixing with one unit out of service.**

**(D) Operations and Maintenance**

**1. Provide elevated walkways for rotor maintenance.**

**2. Rotor weight shall not be supported directly by gear reduction or motor equipment.**

**3. Protect motors, gear reduction equipment and bearings from inundation and rotor spray.**

**(8) Sequencing Batch Reactor**

**(A)General. The minimum total basin volume shall be equal to the design daily influent flow volume and either upstream in-line or off-line storage is necessary to minimize influent flow during settling and decanting**

**1. For design flow less than one hundred thousand gallons per day (0.1 MGD), a minimum of two reactor basins are required.**

**2. For design flows between one hundred thousand gallons and one million gallons per day (0.1-1.0 MGD), three reactor basins are required.**

**3. For design flows equal to or greater than one million gallons per day (1 MGD), four reactor basins are required.**

**(B). Design.**

1. **Design each reactor to operate in a cyclic mode with sufficient time to fill, aerate, settle and remove the clarified liquid.**
2. **Organic loading shall be between 5 to 20 pounds of BOD per thousand cubic feet per day.**
3. **Design the system using food to mass (F/M) ratios of 0.05 to 0.10.**
4. **The total reactor volume shall provide at least eighteen (18) hours of hydraulic detention time. Size the reactor volume on the hydraulic retention time and decant volume.**
5. **The design operating levels shall be 10 to 20 feet with at least eighteen inches (18") (460 mm) of freeboard at maximum liquid level.**
6. **The aeration tank volumetric loading should not exceed 15 lb $BOD_5$/d/1000 $ft^3$ [0.24 kg $BOD_5/(m^3 \cdot d)$].**
7. **The reactor MLSS and MLVSS concentrations and aeration tank volumetric loading should be calculated at the low-water level.**
8. **The minimum sidewater of a SBR tank shall be ten feet (10').**
9. **A SBR with two tanks or a SBR system operating with a continuous feed during settling and decanting phases must include influent baffling and physical separation from the decanter.**
10. **A SBR system must have a dedicated means of transferring solids between aeration basins.**
11. **Each SBR tank must include an overflow to another aeration tank(s) or a storage tank.**
12. **Design for no more than four operating cycles per day per reactor at average design flow.**
13. **Influent baffling using a baffle wall and adequate physical separation of the influent from the decanter shall be provided for any basin which may operate with a continuous feed during the settle and decant phases.**
    a. **The baffling must direct the influent wastewater below the sludge blanket.**
    b. **Average horizontal velocities through each baffle wall opening should not exceed 1 ft/sec (0.3 m/sec) at design peak-hour flows**
14. **System reliability with any single aeration tank unit out of service and the instantaneous delivery of flow shall be evaluated in the design of decanter weirs and approach velocities.**
15. **A high liquid level overflow shall be provided between basins. The overflow shall be located as far as possible from the outlet device and in no case be closer than 10 feet from the outlet device.**
16. **Inlets to each basin shall be located as far as possible from the outlet and in no case be closer than 10 feet from the outlet.**

**(C) Aeration.**

1. **The aeration equipment shall be suitable for varying water depths and cyclical operation in a sequencing batch reactor based on experience with installations handling similar wastes and loadings. The aeration and/or mixing equipment also shall not produce flow patterns within the aeration tank which interfere with quiescent settling. The discharge pressure of the blowers must be established at the maximum water depth. Fixed decanters should not be used in basins where simultaneous fill and decant may occur, or where the sludge may be difficult to settle**
2. **The blowers shall be provided in multiple units, so arranged and in such capacities as to meet the maximum air demand in the oxic portions of the fill/react and react phases of the cycle with the single largest unit out of service.**
3. **The blowers shall be sized to deliver the total oxygen demand in a shorter period of time than allocated to the fill/react and react phases of the cycle if oxic and anoxic conditions are required during these phases.**

**4. Mechanical mixing independent of aeration shall be provided for all systems where biological phosphorus removal or denitrification is required. The mixing equipment should be sized to thoroughly mix the entire tank from a settled condition within 5 minutes without aeration.**

**5. Aeration equipment must provide**

**A. at least 1.4 lbs. of oxygen per lb. of BOD removed at a minimum residual dissolved oxygen level of 2.0 mg/l during the aeration period.**

**B. Where nitrification is required, the aeration equipment shall have the capacity to provide an additional 4.6 lbs. of oxygen per lb. of ammonia nitrogen.**

**6. Oxygen transfer rates from the aerators based on average water depth between the low-water level and the maximum water level for the critical flow conditions.**

(D) Decanter System. **Floating decanters or similar mechanical devices which allow the treated effluent to be drawn near the water surface throughout the decant phase are recommended for added process control.**

**1.The decantable volume and decanter capacity of the sequencing batch reactor system with the largest basin out of service should be sized to pass at least seventy-five percent (75%) of the design maximum day flow without changing cycle times.**

**2. A decantable volume of at least four (4) hours with the largest basin out of service based on 100 percent of the design maximum day flow is permissible.**

**3. Decanters that draw the treated effluent from near the water surface throughout the decant phase are recommended.**

**4. The decanter design must control the velocity at an inlet port or at the edge of submerged weirs to prevent vortexing, disturbance of the settled sludge, and entry of floating materials.**

**5. The entrance velocity to a decanter must not exceed 1.0 fps at the maximum design flow condition**

**6. Design the decanter system to draw effluent from twelve to eighteen inches (12-18") below the surface and to prohibit floating scum from entering the system during fill and aeration periods.**

**7. Decanters must maintain a zone of separation between the settled sludge and the decanter of no less than twelve inches (12").**

**8. Decanters must prevent solids from entering during a react cycle by**

**A. physically raising the decanter above the water surface,**

**B. recycling treated effluent to wash out solids trapped in a decanter, or**

**C. mechanically closing a decanter when it is not in use.**

**9. A fixed decanter may be used except in a basin where simultaneous fill and decant may occur. Two trains or floating decanter are acceptable alternatives.**

**10. A SBR with a fixed level decanter must include a means of positively preventing the flow of mixed liquids into the decanter and additional decantable storage volume because of the added settling time before a discharge may occur.**

**(E) Scum Management**

1 **. Scum removal shall be provided. An adequate zone of separation between the sludge blanket and the decanter(s) shall be maintained throughout the decant phase.**

**2. Scum baffles or other suitable arrangements shall be provided to prevent scum from being withdrawn with the effluent.**

**3. Entrainment by mixing shall not be the sole means of scum control. Scum removal facilities, such as telescoping valves or high-water overflows, should be provided.**

**4. Prevailing winds should be considered in scum control.**

**(F) Sludge Management**

1. **A system separate from the decant piping allowing sludge to be wasted during the decant and/or idle phases of each process cycle shall be provided. The location point(s) in the SBR tank for sludge wasting should be removed from the decanter(s) if wasting may occur during the decant phase.**
2. **The capability to transfer sludge from each basin to the other aeration tank(s) shall be provided. If decant pumps are used for sludge transfer, all solids in the decant piping shall be flushed and recycled back to the SBR.**
3. **All sludge transfer and wasting pumps should be accessible for maintenance without dewatering the\ tank.**
4. **Sludge production depends on the mode of operation.**
   - **A. For extended aeration mode (24 hours retention time), base sludge handling design on a minimum sludge production of 0.5 lbs. per lb. of BOD removed.**
   - **B. For conventional activated sludge mode, or for systems using more than two cycles per day, base sludge production on 0.75 to 0.95 lbs. per lb. of BOD.**
5. **Base sludge storage requirements on a concentration of 8,000 mg/l with a specific gravity of 1.02 for the settled sludge. Base the calculated sludge volume on the liquid depth after decanting.**
6. **Waste sludge control facilities shall have a rate per day equal to 50% of the total basin volume.**

**(F) Operations and Maintenance.**

1. **All projects shall consider the means and frequency for removal of grit and other debris from the SBR basins. Adequate space for equipment access (possibly cranes) should be considered, especially if the tanks are deep.**
2. **At a facility that is not staffed 24-hours each day, each SBR tank must include a high-level alarm that notifies facility staff.**
3. **A programmable logic controller (PLC) shall be provided. Multiple PLCs should be provided as necessary to ensure rapid process recovery and minimize the deterioration of effluent quality from the failure of a single controller.**
4. **An uninterruptible power supply with electrical surge protection shall be provided for each PLC to retain program memory (i.e., process control program, last-known set points and measured process/equipment status, etc.) through a power loss. A hard-wired backup for manual override shall be provided in addition to automatic process control. Both automatic and manual controls shall allow independent operation of each tank. In addition, a fail-safe control that cannot be adjusted by the operator shall be provided, allowing at least 20 minutes of settling between the react and decant phases.**

**(9) Membrane Bioreactor**

**(A) General.**

**1. Wastewater treatment plants with a flow:**

- **A. Equal to or greater than one million gallons per day (1 MGD)(1.55 cfs), the MBR process must be designed to treat the daily average flow with one membrane train/tank out of service (e.g., 4 design tanks + 1 out of service = 5 total).**
- **B. Greater than one hundred thousand gallons per day (0.1 MGD) and less than one million gallons per day (1 MGD)(1.55 cfs), the MBR process must be designed to have at least four membrane trains.**

**C. Equal to or less than one hundred thousand gallons (0.1 MGD), the MBR process should be designed to have two membrane trains but may be designed to have a single membrane train provided:**

**1. The design includes provisions to manage flows during CIP and recovery cleaning (e.g., temporary storage, provisions to remove/replace individual rack/cassette for separate cleaning without impacting remainder of membranes in the tank).**

**2. Design flux criteria must be satisfied with one membrane rack/cassette out of service in each membrane train (e.g., for external CIP, recovery cleaning, repair). For purposes of these criteria, a membrane rack/cassette is the smallest membrane unit capable of separate removal from the tank while maintaining operation of other membrane units in the same tank.**

**3. Membranes may be placed in the aeration basin(s) rather than a separate membrane tank, if the following are satisfied:**

**i. individual racks/cassettes and individual diffusers can be removed separately for maintenance and repair, and**

**ii. the aeration basin(s) volumes are sized for complete nitrification.**

**2. Membranes.**

**A. Use of a membrane system other than a hollow fiber system, tubular system, or a flat plate system will be considered new treatment technology and subject to 10 CSR 20-8.140(5).**

**B. Use of a membrane material other than one of the following must be justified in the facility plan:**

**1. polyethersulfone (PES);**
**2. polyvinylidene fluoride (PVDF);**
**3. polypropylene (PP);**
**4. polyethylene (PE);**
**5. polyvinylpyrrolidone (PVP); or**
**6. chlorinated polyethylene (CPE).**

**C. The nominal pore size used in an MBR process should be equal to or less than four tenths (0.4) microns.**

**(B)Pretreatment.**

**1. Each MBR system must have fine screening to prevent damage from abrasive particles or fibrous, stringy material.**

**2. Fine screens must be rotary drum or traveling band screen with either perforated plate or wire mesh with an opening size of less than or equal to two millimeters (2 mm) for hollow fiber systems and tubular systems and two to three millimeters (2.0 - 3.0 mm) for flat plate systems and must be consistent with membrane manufacturer requirement**

**A. Bypass of a fine screen must be prevented with either a duplicate fine screen, overflow to a wet well, or an alternative that has been approved by the executive director.**

**B. A fine screen must be designed to prevent overflow at the peak flow.**

**C. Coarse screens followed by fine screens may be used in larger facilities to minimize the complications of fine screening.**

**3. Oil and grease removal is required to prevent fouling of the membranes if the oil and grease levels in the influent may cause damage to the membranes. The specific detrimental concentration must be determined by the equipment manufacturer.**

**4. Grit removal shall be provided if primary clarification is not provided.**

**(C)Design.**
**1. The MBR system (including membranes and flow equalization) must be sized to hydraulically pass peak instantaneous flows anticipated in the MBR reactors.**
**2. The design operational range of mixed liquor suspended solids concentration (MLSS) must be:**
**A. at least 4,000 mg/l but not more than 10,000 mg/l in the bioreactor; and**
**B. at least 4,000 mg/l but not more than 12,000 mg/l in the membrane tank.**
**3. The summary of design must identify the average day, peak hour, and peak day flux based on design temperature, solids concentration, and solids retention time.**
**A. An average daily net flux rate of not more than 15 gallons per day per square-foot of membrane area (gfd);**
**B. A peak daily net flux rate equal to or less than 1.25 times the average daily net flux rate; and**
**C. A two-hour peak net flux rate equal to or less than 1.5 times the average daily net flux rate.**
**4. Facilities that expect a peak instantaneous flow rate greater than 2.5 times the maximum month average daily flow must accommodate higher flows with equalization volume, off-line storage or reserve membrane basin capacity.**
**5. Flux rates other than these requirements may be considered on a case-by-case basis (e.g., demonstrated long-term performance data, adequate safety factors).**
**6. The design solids retention time (SRT) shall be at least 10 days but no more than 25 days. For site-specific deviation requests, the design basis justification must include long-term process data from operational facilities to demonstrate no detrimental impacts on membrane operation and permeability.**
**7.The design must include provisions for scum and foam control.**
**A. Scum and foam must not interfere with treatment or overflow a treatment unit.**
**B. Surface wasting of excess mixed liquor or skimmers may be used to control scum and foam.**
**C. Surface wasting may be performed in an aerated basin, a membrane basin, or both.**
**(D)Filters Pressure**
**1. The operational pressure range for hollow fiber transmembrane pressure (TMP) must be at least two pounds per square inch (2.0 psi) but not more than ten pounds per square inch (10.0 psi).**
**2. The operational pressure range for flat plate TMP must be at least three hundredths of a pound per square inch (0.3 psi) but not more than three pounds per square inch (3.0 psi).**
**3. The operational pressure range for tubular, out of basin tubular, Out of Basin TMP must be at least five hundredths of a pound per square inch (0.5 psi) but not more than five pounds per square inch (5.0 psi).**
**(E) Aeration.**
**1. Aeration tank volumes and the selected aeration system must be capable of providing the predicted oxygen uptake rate (OUR) at the design MLSS concentrations.**
**2. A bioreactor aeration system must compensate for a low oxygen transfer efficiency due to the higher MLSS concentrations with a justified alpha value of 0.5 or lower. The summary of design shall provide a clear rationale for the α-value selected. Higher mixed liquor concentrations are expected to result in lower design α-values than for conventional activated sludge.**
**3. The design must include aeration blowers to provide adequate air for membrane scour and process requirements.**
**4. The design oxygen concentration range used for sizing aeration systems for treatment zones must be:**

**A. Anoxic: not more than 0.5 mg/l;**
**B. Aerobic: at least 1.5 mg/l but not more than 3.0 mg/l; and**
**C. Membranes: at least 2.0 mg/l but not more than 8.0 mg/l.**

**5. Mixers.**
**A. Unaerated (deoxygenation, pre/post anoxic, and anaerobic) zones must have submersible mixers or an alternative mixer that has been approved by the department.**
**B. Coarse bubble air diffusers may be used for mixing in a pre-anoxic tank.**

**6. Recycle Rates. Facilities without advanced treatment must be designed with recycle rates sufficient to sustain the design mixed liquor concentrations; typically from two hundred to four hundred percent (200% to 400%) of the facility's influent flow.**

**7. The design must include oxygen monitoring and an alarm to notify an operator of potential or actual oxygen depravation.**

**(E) Redundancy.**

**1. A facility must have the ability to run in full manual mode in case of an automatic control failure. An operational backup programmable logic controller (PLC) is required if manual control is not possible.**

**2.. The facility shall have sufficient standby power generating capabilities to provide continuous flow through the membranes during a power outage (e.g., preliminary screening, process aeration, recycle/RAS/permeate pumps, air scour, vacuum pumps) or an adequate method to handle flow for an indefinite period (e.g., private control of influent combined with contingency methods).**

**(F) Nutrient Removal.**

**1. A system designed for enhanced nutrient removal must include an isolated tank or baffled zone for anoxic treatment, anaerobic treatment, or both.**

**2. Calculations for sizing the reactor volumes must be based on one of these models for nutrient removal:**
**A. Bardenpho;**
**B. Modified Ludzak-Etinger;**
**C. University of Capetown; or**
**D. An alternative approved by the department.**

**3. A facility designed for nitrogen or biological nutrient removal must contain a deoxygenation basin, a larger anoxic basin, or another method approved by the executive director of decreasing dissolved oxygen concentration, if the recycled activated sludge is returned to an anoxic or anaerobic basin.**

**4. An advanced nutrient removal system must be designed with recycle rates sufficient to sustain the designed mixed liquor concentrations in both the aeration and anoxic basins; typically totaling six hundred percent (600%) or more of the influent flow.**

**(G) Disinfection. MBRs utilizing membranes with a pore size no larger than four tenths microns (0.40 µm) is a proven and acceptable means of wastewater disinfection.**

**(H)Sludge Recycling and Wasting**

**1. Design sludge recycle rates for MBR systems must be at least four hundred percent (400%) of influent flow. The Summary of Design must include justification for the selected recycle rate, taking into account peak hour flows and dissolved oxygen requirements in the aeration basin.**

**2. Sludge recycle pumps must include provisions for operator adjustment.**

**3. The design must consider prevention of excess dissolved oxygen from entering anoxic and anaerobic zones or account for oxygen recycle.**

**4. The design must identify location(s) and metering of waste sludge flow (e.g., membrane basin, aeration basin, recirculation lines, or basin surfaces).**

**(I) Operations and Maintenance.**

**1. The MBR design must include provisions for the operator to monitor membrane integrity. For a treatment plant with maximum month flows greater than or equal to one hundred thousand gallons (0.1 MGD), on-line continuous turbidity monitoring of filtrate or an equivalent must be provided for operational control and indirect membrane integrity monitoring.**

**2. Operational control parameters.**

**A. In-line continuous turbidity monitoring of filtrate from each membrane train or cassette or an equivalent must be provided for operational control and indirect membrane integrity monitoring. If turbidity is used for indirect integrity monitoring, the value that indicates problems must be less than or equal to one nephelometric turbidity units (1.0 NTU).**

**B. An owner must follow the manufacturer's recommended frequency for MBR component inspection, testing, and maintenance. The inspection, testing, and maintenance procedures and frequencies must be included in the facility's operation and maintenance manual.**

**C. An owner must provide a facility operator access to any specialized tool necessary for the operation or maintenance of an MBR system. A description of all specialized tools and instructions for their use must be included in an operation and maintenance manual for the facility.**

**3. Cleaning. The MBR design must include provisions for the operator to remove membrane cartridges for cleaning considering the membrane cassette wet weight plus additional weight of the solids accumulated on the membranes. The design shall identify an appropriate combination of cleaning strategies to maintain membrane permeability.**

**A. Hollow fiber membrane cleaning methods typically include air scour, backpulse/backwash, chemical backwash, clean in place (CIP), chemically enhanced backwash (CEB), and recovery cleaning.**

**B. Flat plate membrane cleaning methods typically include air scour, relaxation, and CIP.**

**C. A crane, hoist or some other process or mechanism must be provided for periodic cleaning and maintenance.**

**4. Chemical Use and Disposal. The chemicals used in treatment and maintenance must not harm the MBR system or interfere with treatment. The chemicals, including concentrations and disposal methods, must be identified in the report.**

**(10) Integrated Fixed Film Activated Sludge**

**(11) Moving Bed Bioreactor**

**(12) Biological Nitrification.**

**(A) Biological nitrification is a process whereby autotrophic nitrifying bacteria convert ammonia nitrogen to nitrate nitrogen.**

**1. This process is capable of removing most of the nitrogenous oxygen demand from domestic wastewater but does not remove the nitrogen itself.**

**2. Should nitrogen removal be required, denitrification facilities must follow nitrification facilities.**

**3. If adequate performance data are not available, pilot plant evaluation for a particular application shall be completed prior to a full scale design proposal for upgrade of existing facilities.**

**(B) Single stage design. Single stage systems should be considered for cases where nitrification must be provided only during periods when wastewater temperatures are above 13°C (55°F). For cases where nitrification must be provided for prolonged periods of temperatures less than 13°C, two stage activated sludge, biological nutrient removal, or combinations with fixed film growth systems should be considered.**

**1. The reactor design shall prevent short-circuiting. Plug flow basins should be used, with consideration given to dividing the reactor into a series of compartments by installing dividers across the basin width with ports through the dividers.**

**2. The aeration capacity shall be sized for the peak ammonia load. Where data are not available on ammonia variation, a peak hourly ammonia load (lbs/day) of 2.5 times the average load (lbs/day) should be assumed.**

**3. The aeration supply should have a capacity determined by the following formula where automated blower controls linked to D.O. probes are provided:**

**Aeration supply = 800 cu. ft. per total pounds of ($BOD_5$ +NOD)**

**where: NOD = 4.6 x total Kjeldahl nitrogen (TKN)**

**$BOD_5$ = 5 day BOD entering the aeration basin**

**4. The peak $BOD_5$ and NOD must be used to ensure around-the-clock nitrification. The above air quantity should be doubled if automated blower controls are not provided. The design should maintain a D.O. concentration greater than 1.0 mg/l.**

**5. Aeration basin detention time should be based upon pilot plant data on the specific wastewater involved. Proper control of industrial discharges must be provided to minimize the possibility of biological toxins upsetting the nitrification rates. The following minimum criteria are suggested for municipal wastewaters free of significant industrial wastes and which are subjected to primary settling prior to aeration.**

**A. Sludge age = 10 days or more and F/M = 0.25 or less where: F/M = total daily lbs $BOD_5$ to aeration basin divided by average lbs active biomass in aeration tank.**

**B. Active biomass is measured by the volatile portion of the suspended solids concentration within the aeration basin (MLVSS).**

**6. Nitrification will destroy 7.2 lbs of alkalinity per pound of NH3-N oxidized. If the wastewater is deficient in alkalinity, alkaline feed and pH control must be provided. Sufficient alkalinity should be provided to leave a residual of 30-50 mg/l after complete nitrification.**

**7. The design of final clarifiers will be similar to secondary clarifiers serving suspended growth reactors. The basin shall be equipped with a surface skimming device. A minimum biomass return rate of 25% and a maximum of 100% of the average daily flow shall be provided.**

**(C) Two-stage design. To assure year round nitrification, a two-stage system is considered necessary.**

**1. The $BOD_5$ entering the second stage should be 50 mg/l or less to prevent a washout of the nitrifying bacteria.**

2. **Properly operated contactors or high rate activated sludge systems should provide acceptable first stage systems. The second stage activated sludge system should remove at least 50% of the remaining $BOD_5$ and provide oxidation of 85% to 100% of the ammonia nitrogen.**
3. **The aeration basin should be of the plug flow type with a minimum of three baffled chambers. The basin should be sized to handle the "design peak" ammonia load at the lowest expected operating temperature and optimum pH.**
4. **Available information indicates that the optimum pH for nitrification of wastewater ammonia will be in the range of 8.2 to 8.6. It is recommended that the following information be used for guidance until additional operational information is available concerning the effect of pH:**

| pH | Fraction of Optimum Nitrification Rate |
|---|---|
| 8.4 - 8.6 | 1.00 |
| 8.2 | 0.98 |
| 8.0 | 0.95 |
| 7.8 | 0.88 |
| 7.6 | 0.80 |
| 7.4 | 0.68 |
| 7.2 | 0.58 |
| 7.0 | 0.48 |
| 6.8 | 0.38 |
| 6.6 | 0.30 |
| 6.4 | 0.24 |
| 6.2 | 0.18 |
| 6.0 | 0.13 |

5. **Lime feed capability should be provided to maintain the pH in the aeration basin within optimum range. Quantities of lime needed should be based on**
   A. **pH adjustment of incoming wastewater,**
   B. **destruction of natural alkalinity of 7.1 lb $CaCo_3$/lb NH3 oxidized, and**
   C. **maintaining residual alkalinity of 30-50 mg/l.**
   D. **When adequately buffered wastewaters are treated, it may be more economical to add additional tank capacity in lieu of operation at optimum pH.**
6. **Where performance data or pilot plant data are not available, the following nitrification rates may be employed in the design of the aeration basin. These rates are established for optimum pH. If the design is based on a pH range other than the optimum range, the nitrification rates should be reduced.**

| Temperature (°C) | Nitrification rate-lbs NH3 N nitrified/day/lb MLVSS |
|---|---|
| 5°C | .04 |
| 10°C | .08 |
| 15°C | .13 |
| 20°C | .18 |

| | |
|---|---|
| **25°C** | **.24** |
| **30°C** | **.31** |

**7.A MLVSS concentration of 1,500-2,000 mg/l is recommended.**

**8. Either diffused air or mechanical aeration may be used. The dissolved oxygen concentration in the aeration basin should be based on obtaining 3.0 mg/l during average conditions but should never fall below 1.0 mg/l during peak flow conditions.**

**A. The design of the aeration system should incorporate:**

**1. critical wastewater temperature,**
**2. minimum dissolved oxygen concentration,**
**3. wastewater oxygen uptake rate,**
**4. wastewater dissolved oxygen saturation,**
**5. altitude elevation of the treatment works, and**
**6. aerator efficiency.**

**B. The stoichiometric oxygen requirement of the wastewater can be computed and expressed as daily pounds using the following formula: ($O_2$ required) = $BOD_5$ from 1st stage + 4.6 (TKN)**

**9. This oxygen requirement is somewhat conservative since neither all of the BOD or NOD will be completely satisfied. In order to balance the summer oxygen requirement, provisions for one or more of the following reactor adjustments shall be included:**

**A. Reduce the MLVSS concentration;**
**B. Adjust the pH; or**
**C. Reduce the volume in service and increase the oxygen supply in remaining volume.**

**10. Design information for optimum settling rates is limited. However, it is recommended that the final clarifier design be similar to secondary clarifiers when operating data or pilot plant information is not available. A sludge return capacity of 100% to 150% of the average flow is recommended. Continuous and intermittent sludge removal capability should be provided. The waste sludge quantities typically will be small in comparison to first stage activated sludge quantities and may be combined with first stage activated sludges for further processing.**

**(D) Fixed film design. Various types of attached growth or fixed film unit operations have been studied to determine their ammonia removal capabilities. Conventional standard rate contactors can provide a significant amount of nitrification during warm months but, in general, do not provide consistent year round nitrification. As in the suspended growth systems, a separate fixed film unit operation for nitrification is also deemed necessary to maintain consistent year round performance. However, the use of fixed film biomass support surfaces within aeration basins have demonstrated effective nitrification. Biomass support surfaces would typically be located in the downstream end of aeration basins, occupying the last one-third of the basin length**

**1. Contactor type reactors used for nitrification typically include synthetic media for enhancing the surface area to volume ratio, which generally exceeds 25 square feet of total surface area per cubic feet of media volume. These fixed film contactors generally may be classified into one of the following types based on media construction:**

**A. Column or tower (top loaded).**
**B. Submerged surface (plates or strands).**
**C. Rotating disc (partially submerged).**

**2. Numerous variations in features and arrangements of fixed film contactors have been investigated. Significant nitrification should occur through a fixed film reactor, provided that the biomass surface area is properly sized and uniformly loaded with respect to influent levels of soluble BOD and ammonia nitrogen.**

**3.A hydraulic loading of one gpm or less per square foot of specific media surface has resulted in efficient nitrification of secondary effluent.**

**4. The organic loading should be maintained at or below 10 pounds $BOD_5$ per day per 1,000 cubic foot of media surface. The results of pilot plant studies for specific applications should provide design loading values. Review of fixed film nitrification design will be approached on a case-by-case basis. Influent wastewater characteristics affecting nitrification performance include:**

**A. Soluble BOD.**
**B. Ammonia Nitrogen.**
**C. Temperature.**
**D. pH.**
**E. Alkalinity.**
**F. Toxicity (nitrifier inhibitors).**

**5. The values of nitrification performance are valid for wastewater temperatures greater than 16°C (60°F). At a given loading rate, ammonia removal efficiency decreases nonlinearly with decreasing wastewater temperature.**

| Loading Rate (gpm/square foot) | Nitrification Performance % Removal of Ammonia |
|---|---|
| .50 | 90 |
| .75 | 85 |
| 1.00 | 80 |
| 1.50 | 75 |

**(E) Biological Phosphorus Removal**

**1. A treatment plant designed to provide biological phosphorus removal (BPR) must include design information required in previous biological treatment sections for the appropriate technology as well as the requirements indicated below.**

**A The summary of design must specify the process units needed to achieve the required effluent limits.**

**B. The sizes of the anaerobic and aerobic reactors of the BPR system must be based on the degree of treatment required, influent BOD and TP loads, MLSS concentration, and expected mixed liquor temperatures. The design detention time for anaerobic reactors in mainstream BPR processes must be between 30 to 60 minutes and the SRT of the anaerobic reactors between 0.3 to 0.5 days.**

**C. Methods for supplemental volatile fatty acids (VFAs) must be identified. Storage volume provided for supplemental VFAs must be documented in the summary of design relative to the anticipated need, product stability, and supplier availability.**

**D. The BPR system design must consider having alternatives for phosphorus removal (e.g., chemical removal facilities) for process reliability relative to expected process performance and permit effluent limitations.**

**(13) Denitrification**

(*[6]***14**) Other Biological Systems. New biological treatment schemes with promising applicability in wastewater treatment may be considered if the required engineering data for new process evaluation is provided in accordance with 10 CSR 20-8.140(5)(B).

*AUTHORITY: section 644.026, RSMo Supp. 1988.* Original rule filed Aug. 10, 1978, effective March 11, 1979.*

**Original authority 1972, amended 1973, 1987, 1993.*