Design Guideline 220020
High Purity Water Systems

General

This section describes design requirements for high purity water systems generally used to supply laboratory sinks and equipment, typically known as Reverse Osmosis/De-ionized (RO/DI) systems. This guideline also addresses RO make-up for clean steam humidification systems and soft water make-up for boilers.

Related Sections

U-M Design Guideline Sections:
230000 – Basic Mechanical Requirements

U-M Master Specification Sections: (A digitally accessible version is pending; please email AEC-Digital Accessibility Support if assistance is needed)
220514 - Variable Frequency Drives

Schematic Drawings: (A digitally accessible version is pending; please email AEC-Digital Accessibility Support if assistance is needed)
MD 220020 001 High Purity Water System
MD 220020 002 RO MakeUP System Clean Steam Humid
MD 220020 003 Water Softener for Boilers

System Performance Criteria

The A/E shall determine system performance based on a careful evaluation of specific program requirements. High purity water systems typically have high first and ongoing operational costs, therefore the A/E shall take particular care not to "over-specify" the system. The proposed system performance will be presented no later than SD phase, for approval by the U-M Design Coordinator. It shall be updated through CD phase, as the requirements for the exact equipment served becomes more precisely determined.

The A/E shall provide the following design criteria for approval:

- Make-up rate in gpm
- Daily production in gallons per 24 hour day
- Storage tank size (gallons)
- Distribution loop flow rate (gpm) and head (ft.)
- Distribution loop temperature
- Primary DI loop (to storage) product quality: Resistivity (megohm-cm), silica, total organic carbon (TOC), sodium, chloride, sulfate.

- Distribution loop water criteria: Resistivity (megohm-cm) , silica, TOC, sodium, chloride, sulfate, oxygen, boron, particulate (maximum particle size and quantity per unit volume), bacteria (viable per ml), Ph.
- Point where distribution loop water criteria is to be achieved (e.g. at point of use, leaving post filter, etc).
- Outline calculations identifying how make-up rate and distribution flow rate and head were determined

Not all the criteria listed above will apply to a project, for instance TOC limits typically apply to semi-conductor projects, but not to generic research labs. The A/E shall explicitly indicate which criteria are not applicable when providing design criteria for approval.

Water resistivity above 10 megohm-cm (CAP-1) is not typically required for general lab use, however the A/E shall determine exact resistivity requirements based on the program.

Plans and Specification Requirements

Include a clear statement of the system performance criteria within the specification.

- This statement shall include all the system performance criteria listed above.
- Obtain the most recent city water analysis and include it in the specification.
- Include the minimum expected feed-water temperature.
- Indicate that system performance be guaranteed based on the stated feed-water analysis, including temperature.

Plans shall include a detailed system schematic, showing the arrangement of major system components, instruments, meters, isolation valves, gages, etc.

The system schematic shall also indicate make-up flow rate, distribution flow rate, distribution pump GPM and head, and storage tank volume.

The system schematic shall indicate piping materials for feed water, RO water, distribution supply, and distribution return.

Typical Component Arrangement and Requirements

The following sections outline the typical RO/DI system arrangement at U-M and the requirements for individual components, starting at the feed-water input. Outline level schematics for typical RO/DI, RO, and softener systems are provided for reference under the Related Documents section of this Guideline. It is not the intent of this section to dictate exact system arrangement; the A/E shall design a project specific system to meet program requirements. However, variances from this arrangement shall be called to the attention of the U-M Design Coordinator, for approval.

Feed Water

Provide back-flow prevention (BFP) at the feed water input to the system.

Provide a pressure gauge up and downstream of the BFP.

Evaluate the benefit of preheating feed water to improve RO system performance (by improving RO membrane production rate, allowing reduction in RO size). Consider a mixing valve or heat exchanger. Preheating shall be evaluated on large systems (make-up rates above 10 GPM), however its use typically mandates a distribution loop cooling heat exchanger be employed as well.

Feed Water Pre-Filter

Provide simplex 10 micron cartridge (disposable element) filter with bypass. Specify minimum 20" long cartridges. Provide pressure gauges across the filter.

Water Softener

Duplex softener arrangement, demand (flow) initiated type, common brine tank, shall be provided. Very small systems not requiring 24/7 production may utilize a simplex arrangement. For simplex arrangements, specify demand initiated/timer based regeneration type softeners interlocked to prevent RO operation during softener regeneration cycle.

Provide a hard piped bypass around the softener arrangement.

Softeners for boiler water make-up systems shall be duplex demand initiated type.

Brine tanks shall be specified large enough to hold enough salt for 1 month's soft water production. Maximum brine tank height shall be 4 feet. Indicate that the brine tank over-flow is piped to a floor drain.

For systems with make-up rates above 15 GPM or with an estimated salt use in excess of 1000 lb.s/month, bulk brine storage systems shall be provided.

Provide pressure gauges across the softener bank.

Carbon Filter

Provide duplex carbon filter piping arrangement. U-M utilizes a carbon bottle exchange program where a vendor replaces expired carbon bottles, therefore back-washing type carbon filters should normally not be specified and will only be considered on extremely large systems. The design should indicate all required piping for a duplex arrangement including flexible hoses for carbon filter bottle connection. Indicate carbon filters are supplied by U-M.

Provide pressure gauges across the carbon filter bank.

Reverse Osmosis Prefilter

Provide simplex 1 micron cartridge (disposable element) filter without bypass. Specify minimum 10" long cartridges. Provide pressure gauges across the filter.

Reverse Osmosis System

Specify a skid mounted system furnished with controls providing automatic and manual operation. RO system shall include low pressure pump cut-out, relief valve, meters to monitor product and reject flow rates (typically rotometers) and isolation valves to allow pump and membrane change-out.

Provide a resettable totalizing water meter that indicates total RO product produced.

Mixed Bed De-Ionization Bottles (Make-Up Loop)

Not normally required. A pair (or multiple pair on large systems) of mixed bed resin bottles, located upstream of the storage tanks, may be required for ultra-pure/semi projects. The same piping arrangement and bottle exchange requirements described for the distribution loop mixed beds applies. See below.

Resin Trap

If mixed bed DI bottles are provided in the make-up loop, provide a resin trap downstream consisting of a basket strainer with a 1/64" mesh opening strainer element. Provide pressure gauges across the strainer.

Storage Tank(s)

The A/E shall carefully evaluate storage tank size based on program requirements. Minimum tank sizes adequate to hold a 1/2 day's worth of production are typical.

Tanks shall be translucent with a bottom sloped to the outlet connection. Tank vents and over-flows shall be protected by suitable filters. Provide a tank drain piped to a floor drain.

Tanks shall be equipped with clear, flexible plastic tube ("tygon") type site glasses. Provide isolation valves on site glasses. Specify external tank level sensors located in site glass piping that allows disconnecting the site glass tube to test the level controls without draining the storage tank.

Distribution Pumps

Normally provide 100% redundant distribution pumps.

Indicate isolation valves and pressure gauges on the inlet and outlet of each pump, and provide a check valve on the outlet side of each pump.

Provide a means to control pump flow. Variable frequency drives (VFDs) are preferred, except for very small systems. VFDs shall comply with UM master spec section Variable Speed Drives.

Specify a low pressure cutout switch for the distribution pumps.

Due to the relatively fragile piping materials used on RO/DI systems, often at high pressures, a relief valve with discharge routed to the storage tank is recommended.

Ultraviolet Sterilizers (Upstream of Distribution Loop Mixed Bed De-Ionizers)

UV filtration upstream of the mixed beds is not typically required except in special circumstances, such as systems serving semiconductor fabs.

Mixed Bed De-Ionization Bottles (Distribution Loop)

U-M utilizes a mixed bed bottle exchange program where a vendor provides re-generated resin bottles as on-line bottles expire. Therefore the A/E specification should indicate that the mixed beds are provided by UM, i.e. *not* provided by the contractor. The standard bottle size utilized in this program is 3.6 cubic feet. Therefore the A/E shall design the mixed bed "farm" utilizing this bottle size. Since bottle capacity is typically 3-4 gpm/cubic foot of resin, multiple pairs of bottles are normally required. Each bottle pair shall be indicated as piped in series, with a "quality light" located between each bottle pair to indicate when the upstream bottle quality has degraded.

On extremely large systems, larger bottle sizes may be considered, not to exceed 15 cubic foot size. Larger bottle sizes must be approved by U-M Plant Engineering.

Normally Type 1 resins are utilized on U-M laboratory systems. Ultra pure systems (e.g. semi-conductor applications) may require special mixed bed resins, such as virgin semi-conductor grade. Such resin requirements shall be reviewed and approved by the U-M Design Coordinator.

Ultraviolet Sterilizers (Downstream of Distribution Loop Mixed Bed De-Ionizers)

Provide a simplex UV sterilizer downstream of the distribution loop mixed beds.

Provide a hard piped bypass around the UV sterilizer.

Post Filters, Distribution Loop

Provide simplex cartridge (disposable element) type filter with bypass, equipped with 0.2 micron absolute filter elements. Specify minimum 20" long cartridges. Provide pressure gauges across the filter.

Evaluate higher levels of absolute filter performance ("ultra filters") for ultra pure or critical systems (e.g. semi-conductor applications).

Heat Exchanger, Distribution Loop

Provide when the program dictates that a maximum distribution loop temperature be maintained. Evaluate if a distribution loop heat exchanger is required due to feed-water pre-heating or other factors, to maintain loop temperatures within reasonable limits. Give consideration of final RO/DI water use, pipe expansion concerns, etc. Plate and frame type heat exchangers are preferred.

Sample Ports

Provide sample ports at each location shown on the sample system diagram.

Component Redundancy

For critical systems, in addition to the minimum redundancy requirements specified in the above sections, provide:

- Multiple storage tanks (50/50 or similar type arrangement in lieu of a single tank)
- Redundant final filters

Redundancy for other components, though not typically recommended, may be appropriate. A/E shall evaluate with U-M user and U-M Design Coordinator.

Distribution Piping

RO/DI systems shall be designed for continuous circulation, without dead legs. Dead legs are defined as any dead-ended section of pipe more than 4 pipe diameters long that occurs when a valve is closed. Small less critical systems (total distance from point of use in the 100 foot range) may be non-circulating type

Provide a means of balancing and reading (gpm; rotometers one method) each major supply and return sub-loop, for example: on a floor by floor basis.

Hi purity water faucets with barbed terminations should be the recirculating type with integral back flow preventer, spring return handles preferred.

A back-pressure regulator is typically required on the system return main (near the connection to the storage tank).

Diaphragm or butterfly valves should be specified for supply piping downstream of the distribution loop mixed beds. However, in lower grade systems, carefully evaluate the benefit of diaphragm valves due to the high cost of this valve type. Ball valves may be used on returns and else where. Valve material should typically match associated piping material.

Provide pipe hanger details for hanging plastic pipe.

Bare polypropylene piping should not be run in plenum returns.

Piping Materials

Typical piping materials for RO/DI systems shall be as follows:

RO skid to Storage Tank:

- Sch 80 CPVC, solvent joints (all systems)

Storage Tank to inlet of Distribution Mixed Beds:

- Polypropylene (research labs, and ultra pure applications such as semi)

From Distribution Mixed Bed Outlet (and all RO/DI supply piping in building):

- Polypropylene/fused joints (research labs)
- PVDF/fused joints (ultra pure applications such as semi)

RO/DI distribution loop return piping:

- Polypropylene/fused joints (research labs and ultra pure applications such as semi)

The A/E shall carefully evaluate piping materials, considering specific project performance requirements. PVC/CPVC piping may be considered for low grade high purity applications.

For RO systems serving clean steam generators, piping may be Sch 80 CPVC/solvent joints. Specify stainless steel piping near a clean steam generator connection point due to high temperatures in the vicinity of the generator. Provide a check valve in the make-up line near the connection to the generator.

Controls

Specify a complete, central control panel with the following features:

- Distribution loop supply water resistivity and alarm
- Total RO water produced
- Tank level control
- Distribution pump low pressure alarm light
- Distribution pumps off alarm light (activated only if both distribution pumps are statused" off")
- High storage tank level alarm light (latching, requiring manual reset).
- Low storage tank level alarm light (latching, requiring manual reset).
- Common alarm dry contact, for DDC monitoring. To activate upon any alarm condition above, or any alarm condition occurring on the RO skid.
- Panel on/off switch

Though typically not required, the A/E shall consider if other monitoring and alarm features are appropriate, based on the planned use for the system. Small low grade high purity applications may not require all the control features outlined above.

The RO skid shall utilize a PLC based controller. Specify that the vendor shall provide U-M all software, pass codes, etc. to allow U-M full access to the controller programming and settings, as well as a back-up copy of the project specific program.

Electrical

Do not specify a single point power connection for the system. Instead, indicate power connections to the individual components: Softener, RO Skid, control panel, distribution pumps, etc.

The RO vendor shall be designated as providing combination starters for the RO skid pumps, and VFDs (or combination starters) for the distribution pumps.

Start-up/Certification

The entire distribution loop piping system (supply and return) shall be sanitized (with sodium hypochlorite, similar to sanitizing domestic water systems) prior to putting the system into operation. Mixed beds shall not be connected to the distribution piping during sanitization.

The RO/DI system supplier shall provide technicians specifically trained on RO/DI system start-up, for system start-up.

During start-up, the vendor shall, in the presence of U-M, delete the PLC program and demonstrate reloading the back-up copy of the software program.

All systems shall have performance certified by an independent 3rd party, including the taking of samples. On large systems, multiple samples shall be taken, e.g. one per floor. The first sample shall be taken by dumping the system make-up rate for 24 hours, and then taking a sample at a point of use location designated by the owner. The system shall then be run 1 week, and additional sample(s) shall be taken at point of use locations designated by the owner. Specify that a certified performance report shall be provided to the owner.