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Pure Water: A Drop by Drop Process For Selection of Your System

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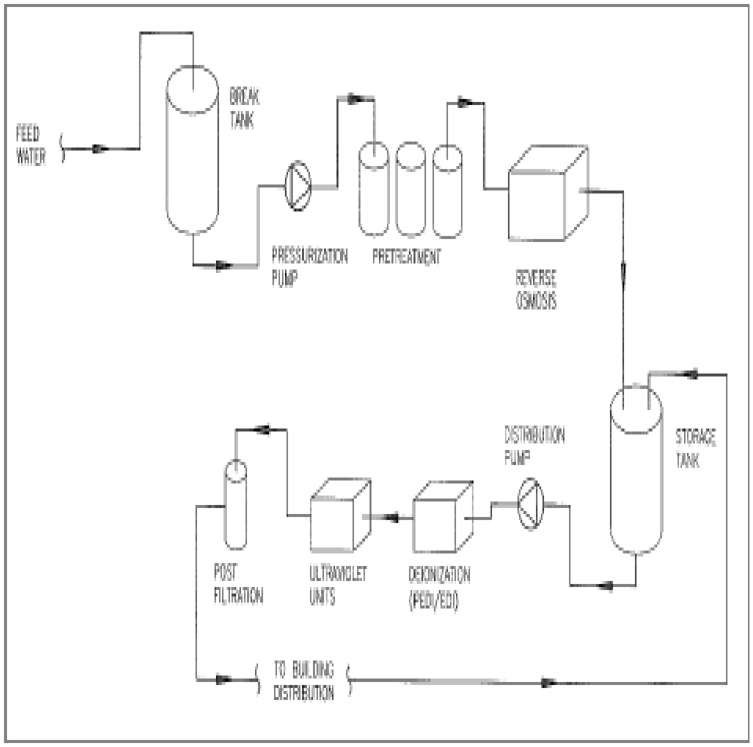
WATER – THE UNIVERSAL SOLVENT

In its purest form, water is one of the most aggressive solvents known and will dissolve a material until the solution reaches saturation. Pure water is also a critical ingredient in many business ventures; manufacturing, power generation, health care, pharmaceuticals, research, food production and processing, etc. Each of these business sectors has a different but specific use for high puritywater. Water purity is relative to its use. Different industries have differentcritical levels or types of impurities; microelectronics – TOCs (totalorganic compounds); power – silica; pharmaceutical – bacteria; research –conductivity/resistivity.The specific purity needs, along with the analysis of the source water, formthe basis of treatment to produce high purity water.

While purity requirements are paramount, another critical selection criterion is the quantity. It would seem obvious that higher volumes of pure water are directly related to equipment selection, redundancy, and serviceability. For example, a system with low-volume demand might effectively accomplish some of the pretreatment filtration functions using cartridge-type filters and closed-loop piping distribution with little or no storage. At the other end of the spectrum, where pure water is fundamental to the process or where extremely high volume demands are normal, a system may be developed with redundant vessels, filters, and pumps to allow for service and/or replacement of components without interrupting either the production or purification processes.

While both the range of purity and the systems for producing high purity water vary widely, there are several fundamental concepts that should apply to all levels of systems. These fundamentals are areas where a deeper understanding by the owner/user can help the pure water system designer develop a systemthat is both efficient and economical for the selected project.



Water purification process schematic

PRETREATMENT

Long lasting, high-performance water systems require appropriate process selection and routine maintenance. Generally, the process selection begins with a reviewof the pretreatment systems. Pretreatment allows each device or piece of process equipment to operate within its normal parameters. For example, a properly sized and installed particulate filter will protect the very fine openings of reverse osmosis (RO) membranes from becoming prematurely clogged with either ordinary par-ticulates or very large sized impurities, prolonging the life of the expensive membrane material while letting the “low-tech” filter do the heavy lifting. Neglecting the concept of progressive filtration is a common error made by those who are unfamiliar with the processes. Once through, one-size-fits-all approaches are destined for higher cost operation,early failure, and unreliable purity levels.

Aside from particulate filtration, other typical filtration processes include chlorine or chloramine removal (carbon filtration), hardness removal (softening), and biological substance removal (multi-media filtration). Chloramines are chlorine/ammonia compounds used by municipal system purveyors to increase the effective duration of the chlorine. This compounding creates some technical difficulties, as the ammonia is harder to remove than chlorine and often requires larger filters. For larger capacity systems, carbon filters, multi-media filters, and sometimes softeners are used. These are often large, vertical vessels that contain media beds arranged for depth filtration and in-place backwash/ cleaning. Very small systems can sometimes use cartridge-type filters, but these are for very limited applications and require significant material and labor costs to maintain.

Other pretreatment methods to improve performance include:

- -Using break tanks and supply pumps to provide consistent flow and pressure of feedwater
- -Tempering feedwater to achieve a temperature of approximately 77°F, the optimum temperature for pure water

- -Sodium meta-bisulfite injection in very small quantities to improve breakdown of chlorine and chlo-ramines
- -Ultraviolet (UV) irradiation to destroy chlorine/chlo-ramines

REVERSE OSMOSIS
Reverse Osmosis (RO) is a mechanical filtration process that is often the central worker in the high purity water process. An RO filter is a thin, semi-permeable membrane that is fine enough to allow water to cross (under high pressure), but the pores are small enough to reject most other molecules and ions. That would place this operation in the area of hyperfiltration, or 10-4microns. Typical sizes of other particulates for comparison purposes include certain viruses (> 10-3), asbestos (> 10-2), and many bacteria (> 10-1). Pores this fine will permit only a very few molecules of non-water to pass. As with pretreatment, water colder than 77 °F will result in lower flow rates and higher rejection rates. Although as impressive and effective as this process is, it is not very effective in removing dissolved gases, suchas carbon dioxide or chlorine. This process will often yield water that is very good, maybe even acceptable for process use, and it will surely make water that is desirable as a feed-water source for other processes, such as deionization(DI).

As one would expect for any of the high purity water systems, maintenance of an RO system is very important. Excess particulate matter that enters the RO filter will quickly clog and foul the membrane, causing excess pressure drop, low productivity, and possibly even membrane failure. Proper pretreatment is essential to long-lived RO systems. Scaling of the membrane with calcium carbonate, calcium sulfate, barium sulfate, and silica is another common hazard. Again, much of this is preventable with effective pretreatment. Because the system relies on rejecting water mixed with various impurities, it can go a long way toward keeping itself relatively clean. However, throughput will cause membrane fouling to some degree over time. The largest part of maintaining an RO system is cleaning; a skid with mixing tanks, pumps, and automated controls is usually necessary to allow for the proper mixture of solutions and liquid flow rate.

DEIONIZATION (DI)
Deionization is a process of ultra-pure water treatment that uses resin beds to attract ionically charged contaminants, such as dissolved solids or gases. These treatment beds are housed in cylinders that are constructed of or lined with inert materials. Typically, there will be a single-bed cation cylinder (+ charge), followed by a single-bed anion cylinder (- charge), followed by a mixed-bed polisher cylinder. Another common arrangement is a multiple cylinder, mixed-bed system where each tank has both cationic and anionicresins, and water quality increases as it flows through each successive tank.

A properly operating DI system should be able to produce water of at least 18 M -cm resistivity. As the resins attract the ionic compounds and become saturated, the resistivity will begin to fall, indicating regeneration is required. The regeneration process requires not only backflushing for particulates, but also regeneration of the cation with sulfuric acid. The process is similar for anion cylinders except that the regenerating fluid is caustic soda. These extremely hazardous materials typically require that regeneration be performed only in a facility with proper personal safety equipment in addition to wastewater containment and treatment facilities.

Typically, DI systems are leased and the cylinders are exchanged at the customer site as they become exhausted. If service exchange is used, the regeneration treatment would be at another facility that is off-site. Occasionally, these systems are owned by the user who controls and operates all aspects of the treatment cylinders, including regeneration that may be on-site.

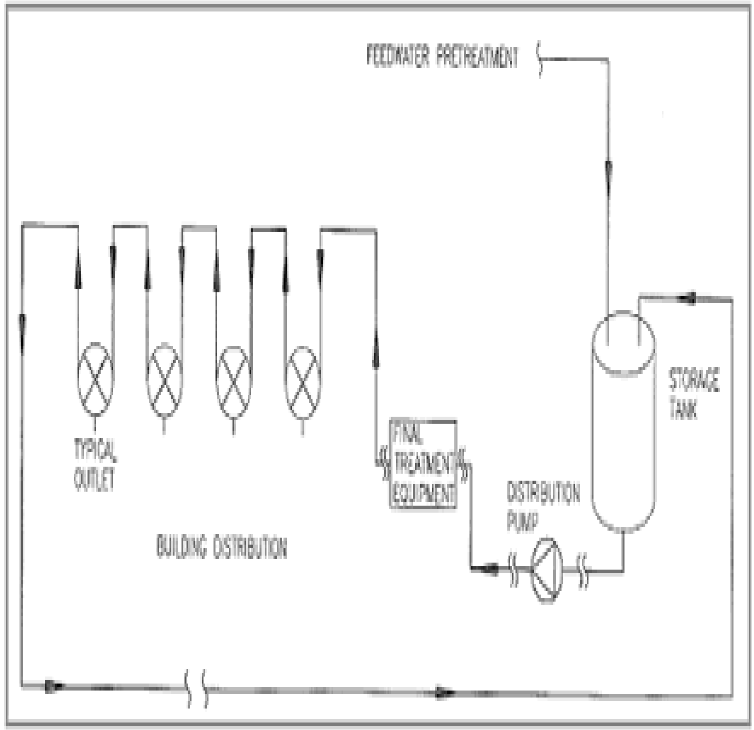
ELECTRO-DEIONIZATION (EDI)

EDI is a technology that has been growing over the past 10–15 years. The marketplace has successfully passed through many roadblocks to get to this point. Currently, it is well considered to be reliable and consistent, and most of the operational and set-up problems have been identified and solutions developed. EDI is not necessarily about electrifying the process of deionization; rather, it electrifies the process of regeneration of the DI resins. The construction of the EDI reactor is remarkably similar to a typical RO membrane reactor, with multiple sheets that form an alternating assembly of resin-impregnated membranes and by-product flow channels. The product water flow is through the resin bed (as with traditional DI stacked beds), and the separation of impurities is by ionic attraction of either anions or cations. The “magic” occurs when the resin is regenerated. By electrical charge, either the anode (+) or cathode (-) attracts the ionized impurities that have collected, and they are flushed to drain. The process can be very much likened to the backwashing ofa filter, except for the detail of electricity.

EDI systems are available in a wide flow range, from 5–2000 gpm. Obviously, their appropriateness is dependent upon the user as well as the quantity and quality of water needed. There are also some higher first-cost issues over chemically regenerated DI systems. However, if a process is properly maintained, then there is the potential for substantial cost savings over the life of the system by avoiding the cost of chemical regeneration of resin (e.g., chemical acquisition, storage, handling, use, and disposal). The EDI system is highly susceptible to failures caused by poor water quality and pretreatment, and failures are exaggerated by field conditions and piping systems that have not been adequately cleaned.

ULTRAVIOLET

Ultraviolet (UV) is a light spectrum that is below the spectrum of visible light, but above that of x-rays. It is produced mechanically/electrically by use of electric arc, mercury vapor-filled chambers. As opposed to viruses, bacteria and other sensitive organisms that are irradiated by exposure to UV light can be effectively sterilized by this medium. Once exposed, the organism will die either immediately or within a short period of time. The germicidal effect is directly related to dosage, which is a product of both intensity and retention time. Therefore, dosage is directly affected by water clarity, reinforcing the need for pretreatment in addition to quality monitoring and management. High turbidity and suspended solids can lead to UV absorption before an effective dosage can be delivered; water hardness can cause scale buildup on the quartz sleeves of the lamp holder and lead to poor transmissionand UV absorption.



Single loop distribution schematic

UV has many advantages, including reaction speed (almost instantly upon exposure). It does not produce toxic byproducts and is safe and chemical-free. UV also adds nothing to the water that must be removed by another process and has a proven record in the water treatment, food and beverage processing, pharmaceutical, and semiconductor manufacturing industries. While advantageous, UV does have a few limitations in application. It provides no post-treatment residual effects, and its effects are greatly diminished by poor water quality and clarity. Whileit can be effective for destruction of both organics and chemicals, it has noeffect on water quality parameters, such as suspended solids.

One area that is a growing field for use of UV is chlorine, chloramines, and ozone destruction as a pretreatment to other treatment methods, such as RO or DI. The increased protection of RO membranes is one aspect of UV for destruction of residual gases that is touted as a benefit, increasing both life and serviceability. This function should be reviewed with a pure water consultant to determine applications and to select the most appropriate lamp intensity and dosage. Because UV is very destructive to most forms of plastic pipes, light traps should be incorporated into inlets and outlets of lamp chambers, and lamp chambers should be constructed of stainless steel for long-lived operations.

DISTRIBUTION SYSTEMS

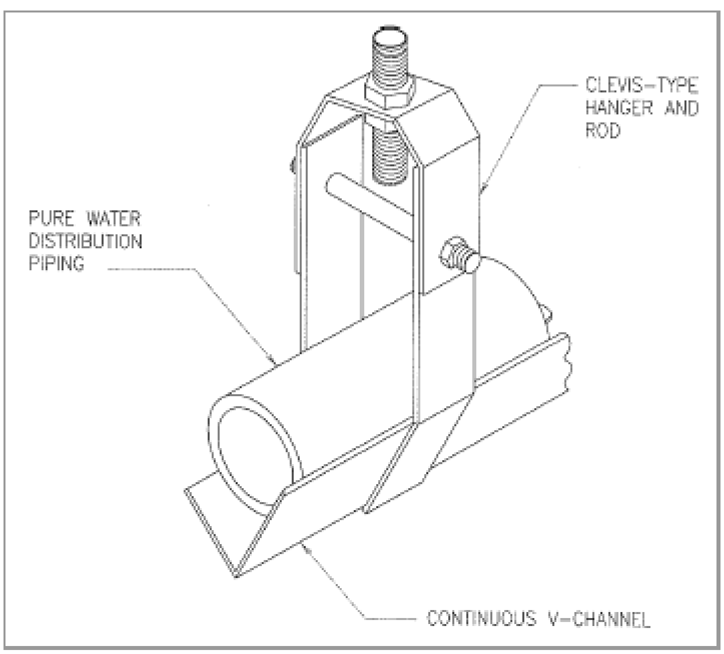
Once the water is purified and is in an ultra-pure condition, the challenge is to distribute it to use points without degradation of quality. This can be as much a challenge as selection of the purification process itself! The aggressive nature of the fluid will make it try to absorb contaminants from the piping system. Extended lengths of piping, filled with warm water and no biocide, provide an excellent medium for bacterial growth and bios lime development. Uncirculated piping drops, or dead legs, provide a superb breeding ground for bacteria and a gathering point for particulate matter or other “sludge.” Balancingpressures and flow rates to help minimize these conditions is critical.

Ideally, the use point for high-purity water would be immediately at the point of production of the water. However, that is not a very prevalent scenario, particularly with larger systems and flow rates. For distribution, some variation of a loop system should be considered. It may be a single, extended loop, or multiple loops, either parallel or in series. Supply and circulation manifolds with constantly flowing branch headers are another variable that may be considered. In all cases, a true loop should be considered for the highest quality water. This means each drop of water from the last outlet would have passed by the branch to each other outlet between it and the source. Further, each branch drop to an outlet should have no dead legs or uncirculated piping length longer than six times the inside piping diameter.

All circulated pure water should be returned to a central storage and polishing location to maintain quality and remove any contaminants introduced from the piping network. When using a storage tank, it should include a drainable bottom, clean-in-place valves on piping connections, and HEPA-filtered vent and nitrogen-blanketed air space. These will help prevent contamination of product water through the tank. Also, connection points for sanitization equipment, whether ozone gas, heat, or chemical sterilization, should be provided.

Pure water piping materials are another critical choice. Glue-joined or threaded systems, such as PVC or CPVC, will leave voids and crevices in the flow stream. These are excellent sites for bacterial growth and the beginning of ruin for the pure water network. Socket-weld polypropylene systems are slightly better, and the butt-fused systems are an even more superior option. The highest quality systems use bead- and crevice-free piping and produce a completely smooth waterway that does not allow ridges or crevices for colony growth sites.

A final aspect for consideration is the piping routing and supports. All plastic piping systems need support at closer intervals than are traditionally used for metal piping. Of course, the piping must compete for space with other piping systems and attachment points for hanger supports. In time, sags will develop between pipe supports, and these may serve as low points for collection of contaminants. A suggested solution is to provide continuous support by placing the piping in a 24 gauge, stainless steel v-channel.



Continuous pipe support

In conclusion, there are many variables and options available in the planning and operation of high purity water systems. Critical aspects of the system will vary with use; options available are often variables based on system capacity and type. In all cases, early planning and discussion is critical for the development of system performance criteria and equipment selection. Once ready to assemble components and develop distribution and operation methods, provisions should be made to allow for service, repair, and replacement of equipment. At a minimum, this should consider expansion capability for equipment or distribution, multiplex equipment to allow for partial component loss without total production loss, and the level of investment for on-site operational and service personnel or contract services.

There are an imposing number of decisions for consideration. While the task seems daunting, the investment of this planning time will make the difference between a smoothly flowing pure water system and an albatross!

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