thermo scientific

Water 101

Thermo Fisher SCIENTIFIC

Lab Water Experts

For more than 130 years, Thermo Scientific lab water systems have been a trusted resource for science and industry. Our complete line of water purification technologies includes solutions for your most critical and everyday application needs, from electrodeionization to reverse osmosis and distillation.

Barnstead lab water systems deliver:

Innovation
Our water purification portfolio features advanced ergonomics and technology, including remote dispensing and UV intensity monitoring – that offer users full control with confidence.

Flexibility
Laboratory environments often have limited bench space. Our portfolio offers numerous mounting options, small footprints and flexible dispensing options to provide you the luxury of designing a configuration that best suits your lab.

Convenience
Our Thermo Scientific H_20 Select analysis program and complete all-in-one box ordering gives you the confidence to select the right solution. Receive a complete water system using one part number and have the components you need to easily maintain your new water purification system.

Innovation

that deliver accuracy

With innovative water monitoring technology, Thermo Scientific water purification systems eliminate expense and lost time which may occur with contaminated lab water.

Advanced feed water monitoring
Alerts the user to fluctuations in the feed water quality. Poor feed water will reduce cartridge life.

TOC measurements with UV intensity monitoring
Continuously monitoring and recording TOC measurements in real-time, this technology ensures ultrapure water that meets or exceeds even the most stringent requirements for sensitive applications. A photo sensor continually checks the intensity of the UV lamp. A drop in measured UV radiation can result in an incorrect TOC measurement.

EDI systems feature tank recirculation to maintain high purity water even during long periods of inactivity
Automatic recirculation of the water in the tank across a special polisher actively protects against bacteria growth even during long periods of inactivity.

Flexibility

system design

Mounting flexibility
Installation options include under the cabinet, on the wall, on the bench, or free-standing units with wheels for added mobility.

Full system control at the Thermo Scientific xCAD remote dispenser
Eliminate the hassle of going back to the primary system to adjust parameters.

Adjustable storage tank
Growing the lab or planning for changing needs? Type 2 and RO systems enable changing water level settings in the storage tank to adapt to the lab's needs.

Dual water quality
Need more than one type of water? Many of the systems produce two types of water from just one system.

Convenience

with customized system selection

Based on the results of a H_2O Select analysis, we will recommend the best water system for your application based on your feed water quality, laboratory applications, daily volume requirements and budget. We do all the thinking for you.

How it works:

1. Contact your local sales representative for a complimentary H_2O Select analysis kit.
2. Fill the sample bottle with your anticipated feed water.
3. Answer the short questionnaire pertaining to your water requirements, applications and budget.
4. Place the completed application and water sample bottle in the return box. Add postage and mail to the Thermo Scientific Barnstead Water Lab (return label included in box).

All-in-one-box ordering
Have confidence in knowing that there are no surprises with added post sale costs. Everything you need ships under one part number!

Easy self maintenance
The Aquastop quick connections make changing your cartridges quick and simple.

Lab Water 101

Common Water Impurities

Don't let impurities contaminate your sensitive experiments. Thermo Scientific Barnstead water purification systems are engineered to remove impurities that threaten your research so you can focus on what's important – your next discovery.

Speaking the language of Lab Water

Application and Interest Areas	Contaminants to Avoid in Your Lab Water: Particulates	Colloids	Ions	Dissolved gases	Organics	Nucleases	Pyrogens
General Lab Purpose							
Autoclave	•	•	•				
Humidification	•	•	•				
Glassware washing/rinsing	•	•	•				
Media preparation	•	•	•				
Analytical							
Ion chromatography (IC)	•	•	•	•			
Atomic absorption (AA)	•	•	•	•			
High performance liquid chromatography (HPLC)	•	•	•	•	•		
Inductively coupled plasma spectroscopy (ICP)	•	•	•	•	•		
Mass spectroscopy (MS)	•	•	•	•	•		
Gas chromatography (GC)	•	•	•	•	•		
Total organic carbon (TOC)	•	•	•	•	•		
Life Sciences							
Genomics (ex. PCR, mutagenesis)	•	•	•	•	•	•	•
Proteomics (ex. crystallography, electrophoresis)	•	•	•	•	•	•	•
Immunology (ex. monoclonal antibody production, blots)	•	•	•	•	•	•	•
Pharmacology	•	•	•	•	•	•	•
Cell and tissue culture	•	•	•	•	•	•	•
Drug discovery	•	•	•	•	•	•	•

Suspended Particles

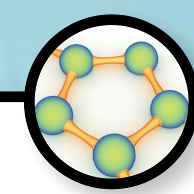
Sand, silt, clay and other suspended particles cause water to be turbid. These suspended particles can interfere with instrument operation, plug valves and other narrow flow paths, and foul reverse osmosis membranes. They typically range from 1 – 10 µm in size.

Colloids

Colloidal particles typically have a slightly net negative charge, range in size from 0.01 – 1.0 µm, and can be either organic or inorganic. Unlike suspended particles, colloids do not settle out by gravity, but remain suspended in the liquid that carries them. Colloids clog filters, interfere with instrument operation, foul reverse osmosis membranes and can bypass ion exchange resins, resulting in lower resistivity in deionized water systems.

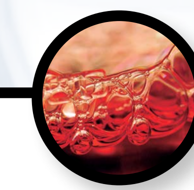
Inorganic Ions

Impurities such as silicates, chlorides, fluorides, bicarbonates, sulfates, phosphates, nitrates and ferrous compounds are present as cations (positively charge ions) and anions (negatively charged ions). Water with a high concentration of ions will conduct electricity readily and have high conductivity and low resistivity, as conductivity and resistivity are inversely related. Ions will adversely affect the results of inorganic analyses such as IC, AA, ICP/MS and may retard cell and tissue growth in biological research. They can also affect the cartridge life in deionized water systems.



Dissolved Organics

Organic solids are present from plant and animal decay and from human activity. They may include proteins, alcohols, chloramines and residues of pesticides, herbicides and detergents. They foul ion exchange resins, interfere with organic analyses including HPLC, gas chromatography and fluoroscopy. They will also hinder electrophoresis, tissue and cell culture.

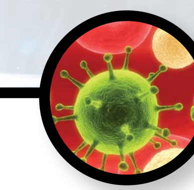


Dissolved Gases

Water naturally contains dissolved gases such as carbon dioxide, nitrogen and oxygen. Carbon dioxide dissolves in water to form weakly acidic carbonic acid (H_2CO_3), which can alter the pH of the water. Additionally, oxygen, the most common non-ionized gas, may cause corrosion of metal surfaces.

Microorganisms

Bacteria, fungi and algae are found in all natural water sources. Chlorination eliminates harmful bacteria, but tap water still contains live microorganisms which interfere with sterile applications, such as cell and tissue culture.



Pyrogens and Viruses

Pyrogens or bacterial endotoxins are lipopolysaccharide molecules incorporated in the cell membrane of gram negative bacteria. Viruses are considered to be non-living nucleic acids. Both can adversely affect laboratory experiments often hindering cell and tissue growth in culture.

Nucleases

RNase and DNase are naturally occurring enzymes that are instrumental in regulating bodily functions. As important as these enzymes are to the life process, they can be devastating to nucleic acid experiments. If these contaminants are present in the lab water used, the ability to amplify DNA molecules will be severely limited. Likewise, experiments utilizing RNA can be ruined.

Lab Water 101 - Thermo Scientific Barnstead Water Purification Technologies

To make pure and ultrapure water, the impurities discussed on the previous page must be efficiently and effectively removed. Barnstead water purification systems employ multiple technologies, some synergistically, to remove impurities and give you consistently PURE water.

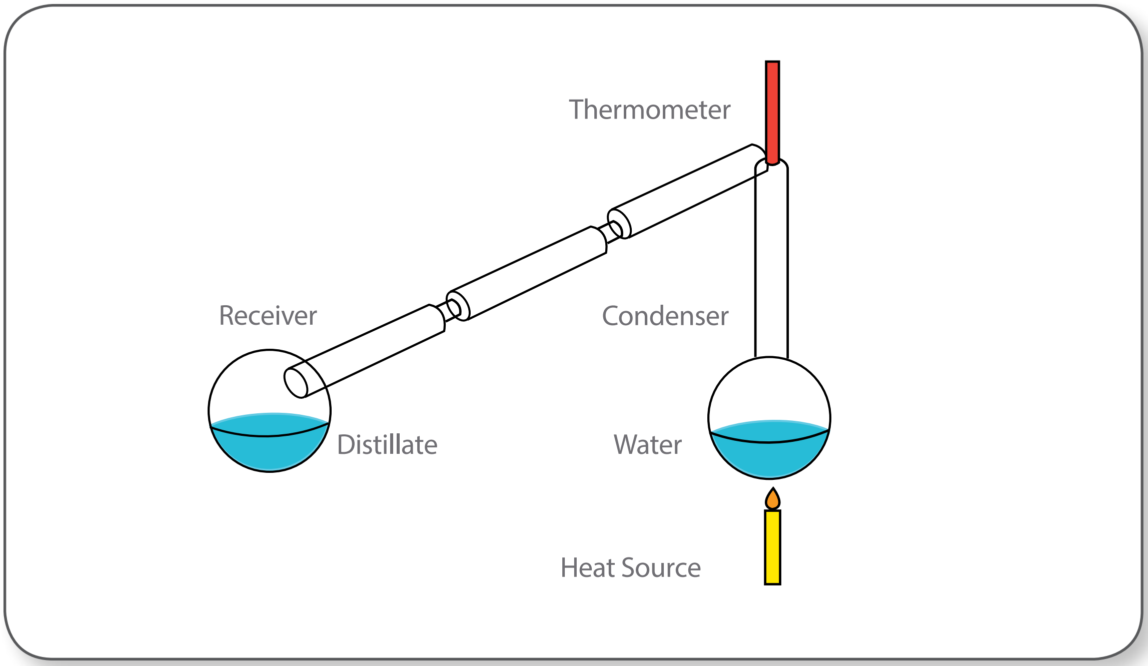
Water purification is a step-by-step process often requiring a combination of technologies, each of which varies in the ability to remove specific contaminants.

The table below illustrates which impurities are removed by each technology.

	Distillation	Reverse Osmosis	Deioization	Electro-deionization	Filtration	Ultrafiltration (UF)	Adsorption	Ultraviolet (UV) Oxidation	Combination UV/UF
Inorganic ions	Excellent	Good	Excellent	Excellent	Poor	Poor	Poor	Poor	Poor
Dissolved gasses	Good	Poor	Excellent	Excellent	Poor	Poor	Good	Poor	Poor
Organics	Good	Good	Poor	Poor	Poor	Poor	Excellent	Excellent	Excellent
Particles	Excellent	Excellent	Poor	Poor	Excellent	Excellent	Poor	Poor	Excellent
Bacteria	Excellent	Excellent	Poor	Poor	Excellent	Excellent	Poor	Excellent	Excellent
Pyrogens	Excellent	Excellent	Poor	Poor	Poor	Excellent	Good	Poor	Excellent
Nucleases	Poor	Poor	Poor	Poor	Poor	Good	Good	Poor	Excellent

- Excellent
- Good
- Poor

Speaking the language of Lab Water



A basic distillation diagram

Distillation

Distillation has the broadest removal capabilities of any single form of water purification.

Water is boiled and undergoes phase changes during the distillation process, changing from liquid to vapor and back to liquid. It is the change from liquid to vapor that separates the water (in various degrees) from many dissolved impurities, such as ions, organic contaminants with low boiling points <100 °C, bacteria, pyrogens and particulates. Distillation cannot be used on its own to remove inorganic ions, ionized gases, organics with boiling points higher than 100 °C, or dissolved non-ionized gases.

Benefits

- Offers the broadest removal capabilities of any single form of water purification
- Requires no consumables

Limitations

- Requires periodic maintenance and manual cleaning of system to maintain water purity
- Requires water for cooling

Systems that utilize this technology

- Barnstead Classic Stills and Mega-Pure Stills

Barnstead Classic Stills

Lab Water 101 - Thermo Scientific Barnstead Water Purification Technologies

Filtration

Barnstead water purification products offer both depth (nominal) and membrane (absolute) filters.

Depth filters are most commonly used as a pretreatment and are manufactured by winding fibers around hollow and slotted tubes. As water passes through the wound fiber matrix toward the center tube particles are retained on the fibers. Traditionally this type of filter removes most of the impurities above the rated pore size of the filter. Most often these filters are rated to remove larger particles (>1 µm) to protect the technologies that follow.

Membrane filters are often termed absolute, meaning that they are designed to remove all particles above the rated pore size of the filter. These filters use a membrane, (in flat sheet or hollow fiber form), and are most often used at the end of a system to remove bacteria or other particles that are not removed by the preceding technologies. Traditionally membrane filters in laboratory water systems have a rated pore size below 0.45 µm, most often 0.2 µm.

Benefits

- Efficient operation
- Maintenance is change out only

Limitations

- Clogging
- Will not remove organics, nucleases, pyrogens, dissolved gases or dissolved inorganics

Systems that utilize this technology

- Thermo Scientific Barnstead GenPure, MicroPure, E-Pure, LabTower EDI, Smart2Pure, Pacific TII, LabTower TII water purification systems

Sterile Filter

Ultrafilter

Ultrafiltration (UF)

In water purification, ultrafiltration is used to remove pyrogens (bacterial endotoxins) and nucleases, which is critical for tissue culture, cell culture and media preparation.

Ultrafilters use size exclusion to remove particles and macromolecules. By design, ultrafilters operate similar to reverse osmosis membranes; particles are captured on the surface of the membranes and are flushed from the membrane via a reject stream. Ultrafilters are used at the end of systems ensuring the near total removal of macromolecular impurities like pyrogens, nucleases and particulates.

Benefits

- Effectively removes molecules (pyrogens, nucleases, microorganisms, particulates) above their rated size
- Long life
- Helps to remove pyrogens and nucleases

Limitations

- Will not remove dissolved inorganics, dissolved gases, and organics

Systems that utilize this technology

- Barnstead GenPure, MicroPure, and Smart2Pure water purification systems

Speaking the language of Lab Water

Reverse Osmosis

Reverse osmosis is the most economical method of removing up to 99 % of feed water contaminants.

To understand reverse osmosis you must first understand osmosis. During natural osmosis, water flows from a less concentrated solution through a semipermeable membrane to a more concentrated solution until concentration and pressure on both sides of the membrane are equal.

In water purification systems, external pressure is applied to the more concentrated (feed water) side of the membrane to reverse the natural osmotic flow. This forces the feed water through the semipermeable membrane. The impurities are deposited on the membrane surface and sent to drain and the water that passes through the membrane as product water is, for the most part, free of impurities.

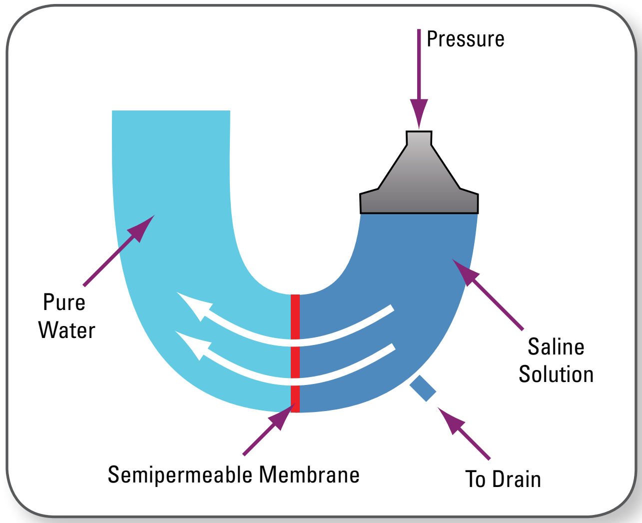
A reverse osmosis membrane has a thin microporous surface that rejects impurities, but allows water to pass through. The membrane rejects bacteria, pyrogens and 90-95 % of inorganic solids. Polyvalent ions are rejected easier than monovalent ions. Organic solids with a molecular weight greater than 200 Daltons are rejected by the membrane but dissolved gases are not as effectively removed.

Reverse osmosis is a percent rejection technology. The purity of the product water depends on the purity of the feed water. The product is typically 95-99 % higher in purity than that of the feed water.

Due to the restrictive nature of the membrane, the flow rate is much slower than other purification technologies. This slow flow rate means that all RO systems require a storage reservoir to provide a constant supply of RO water ready when you need it.

Benefits

- To varying degrees, removes most types of contaminants, bacteria, pyrogens and 90-95 % of inorganic ions
- Requires minimal maintenance



Process of reverse osmosis

Limitations

- Limited flow rates through the membrane require intermediate storage devices to meet user demand
- Does not remove dissolved gases
- Requires pretreatment to avoid damaging the membrane
  > Oxidation – Chlorine
  > Scaling – $CaCO_3$
  > Fouling – Organics and Colloids
  > Piercing – Hard particles

Systems that utilize this technology

- Barnstead Smart2Pure, LabTower EDI, Pacific TII, LabTower TII, Pacific RO, LabTower RO water purification systems

Barnstead Pacific RO and Barnstead Lab Tower RO water systems

Lab Water 101 - Thermo Scientific Barnstead Water Purification Technologies

Deionization

Deionization is also referred to as demineralization or ion exchange.

The process removes ions from feed water with the use of synthetic resins. These resins are chemically altered to have an affinity for dissolved inorganic ions and are divided into two classifications: cation removal resins and anion removal resins.

Cations have a positive charge and include sodium (Na^+), calcium (Ca^{+2}) and magnesium (Mg^{+2}). Anions have a negative charge and include chloride (Cl^-), sulfates (SO_4^{-2}), and bicarbonates (HCO^{-3}). The ions are removed from the water through a series of chemical reactions. These reactions take place as the water passes through the ion exchange resin beds. Cation resin contains hydrogen (H^+) ions on the surface which are exchanged for positively charged ions. Anion resin contains hydroxide (OH^-) ions on its exchange sites which are exchanged for negatively charged ions. The final product of these two exchanges is H^+ and OH^-, which combine to form water (H_2O).

Deionization is the only technology which produces the resistivity requirement for Type 1 reagent grade water. In laboratory water systems, cation and anion resins are most often mixed together allowing them to achieve maximum ionic purity.

Two-bed deionization – The cation and anion resin are in separate halves of a cartridge. In general, this method is less effective deionizing water as compared to the mixed-bed deionization; however, it is more tolerant of other types of impurities.

Mixed-bed deionization – We use semi-conductor grade mixed bed deionization resin to achieve maximum resistivity and low TOC. Mixing the cation and anion resin drives the deionization to completion, making it more efficient and more effective at the removal of ions.

Benefits

- Removes dissolved inorganics ions very effectively
- Produces product water with a resistivity above 18 MΩ.cm

Limitations

- Finite capacity – once all ion binding sites are occupied, ions are no longer retained and the cartridge must be replaced
- Does not remove organics, particles, pyrogens or bacteria

Systems that utilize this technology

- Barnstead GenPure, MicroPure, E-Pure, LabTower EDI, Smart2Pure, Pacific TII, LabTower TII, and the Bantam water purification systems, Hose Nipple, and B-Pure cartridges

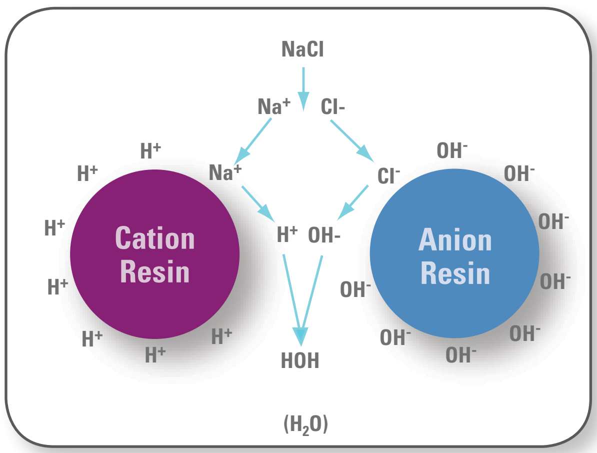
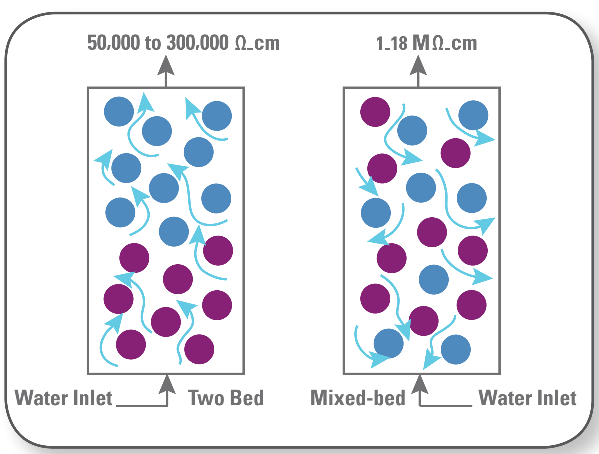
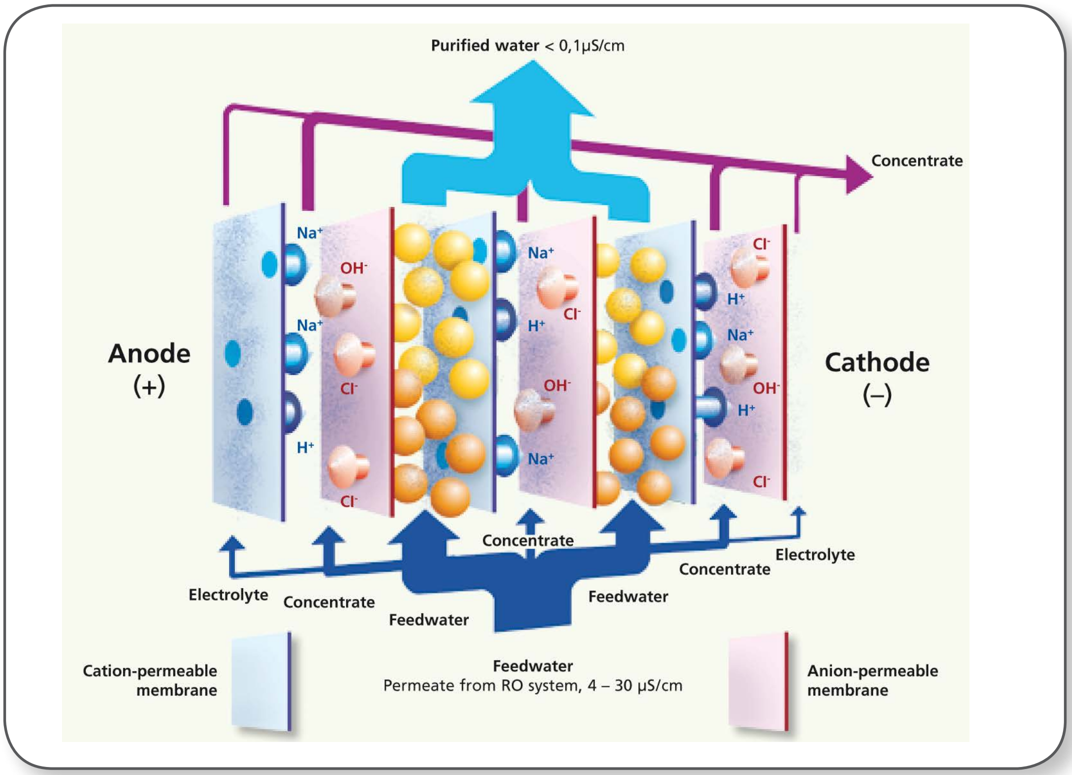


Diagram showing how cations and anions are exchanged on the resin



Two bed resin is shown on the left and mixed bed resin in on the right

Speaking the language of Lab Water



Process of electrodeionization

Electrodeionization (EDI)

In contrast to conventional ion exchange in which resins are exhausted and must either be thrown away or chemically regenerated, EDI utilizes an electric current for continual resin regeneration.

How EDI works

Several layers of ion selective membranes are positioned between an anode and a cathode. Layered ion exchange resin beds and concentrate chambers are alternately positioned between them.

On applying an electric voltage, water (H_20) is split into H+ and OH– in the cell. The H+ and Na+ cations can migrate through the cation permeable membranes, anions through the anion permeable membranes.

The ions migrate in the direction of the applied voltage, i.e. anions to the positive pole (anode), cations to the negative pole (cathode). The water ions H+ and OH– that migrate through an ion exchange chamber displace salt ions retained by the ion exchanger resins and so continually regenerate the resins. The salt ions migrate through the appropriate ion selective membranes into the concentrate chambers and are flushed out of them by water. As all concentration chambers are flushed through one after the other, excess H+ and OH– ions can again combine to form H_20.

Benefits

- Effectively removes ions
- Continuously regenerates automatically

Limitations

- Limited capacity – feed water must be of high quality
- Does not remove organics, particles, pyrogens or bacteria

Systems that utilize this technology

- Barnstead LabTower EDI water purification system

Lab Water 101 - Thermo Scientific Barnstead Water Purification Technologies

Adsorption

Adsorption uses high surface area activated carbon to remove organics and chlorine from feed water.

It is used as a first or second step in most water purification systems and may be used as a final step, in combination with ion exchange resins, to achieve ultra low Total Organic Carbon (TOC). Organics and chlorine adhere to the surface of the activated carbon and remain attached to the carbon.

Mixed-bed deionization and adsorption – We use a combination semiconductor grade mixed-bed deionization resins and synthetic carbon in a single cartridge to achieve maximum resistivity and low Total Organic Carbon (TOC).

Benefits

- Removes dissolved organics and chlorine
- Long life

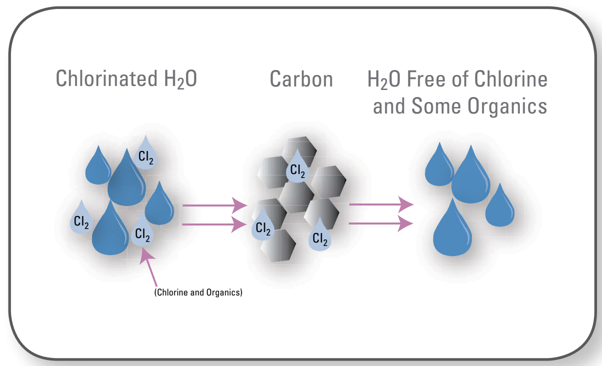
Limitations

- Will not remove ions and particulates

Systems that utilize this technology

- Barnstead GenPure, MicroPure, E-Pure, LabTower EDI, Smart2Pure, Pacific TII, LabTower TII, and the Bantam water purification systems, Hose Nipple, and B-Pure cartridges

Selection of high quality resins used in our cartridges



Feed water with organic and chlorine contaminants come into contact with the activated carbon in the cartridge. The impurities adhere to the surface of the carbon, allowing purified water to be produced.

Speaking the language of Lab Water

Ultraviolet (UV) Oxidation

Photochemical oxidation with ultraviolet light eliminates trace organics and inactivates microorganisms in feed water.

The UV lamps in our lab water systems generate light at two wavelengths, 185 and 254 nm. The light generated at 254 nm has the greatest anti-bacterial action, reacting with their DNA, resulting in inactivation. The combination 185/254 nm light oxidizes organic compounds, allowing for total oxidizable carbon levels of less than 5 ppb.

Benefits

- Effective method to prevent bacterial contamination
- Oxidizes organics to produce pure water with low TOC levels

Limitations

- Will not remove ions, colloids and particulates

Systems that utilize this technology

- Barnstead GenPure, MicroPure, LabTower EDI, Smart2Pure, Pacific TII, LabTower TII water purification systems

Combination Ultraviolet Oxidation and Ultrafiltration (UV/UF)

The use of ultraviolet oxidation and ultrafiltration technologies in conjunction with adsorption and deionization in the same system produces water virtually free of all impurities. These technologies have demonstrated the ability to remove nucleases such as RNase and DNase as well as pyrogens when challenged with known concentrations of the material. The Type 1 systems with UV/UF options produce reagent grade water with resistivity up to 18.2 MΩ.cm, TOC of 1-5 ppb, pyrogens <0.001 EU/mL and no detectable RNase, DNase or DNA.

Benefits

- Removes nucleases and DNA
- Produces water with low TOC and pyrogen levels

Limitations

- Must be used in the same system

Systems that utilize this technology

- Barnstead GenPure, MicroPure, and Smart2Pure water purification systems

Lab Water 101 - Internation Water Standards

What Does Type 1 Water Mean?

Reagent water has quantitative specifications that describe the level of purity for the water. These specifications have been described by ASTM (American Society for Testing and Materials) D1193, ISO (International Organization for Standardization) 3696 and CLSI®-CLRW. (Clinical and Laboratory Standards Institute-Clinical Laboratory Reagent Water). The most commonly used standards, ASTM D1193-6, are summarized in the tables below.

ASTM Standards for Reagent Water			
Measurement (unit)	**Type I**	**Type II**	**Type III**
Resistivity (MΩ.cm) at 25 °C	>18	>1	>4
Total organic carbon (ppb)	<50	<50	<200
Sodium (ppb)	<1	<5	<10
Chloride (ppb)	<1	<5	<10
Total silica (ppb)	<3	<3	<500

The ASTM standards are further subdivided into A, B and C.
These standards can be used in conjunction with the Type of water.

ASTM Standards for Reagent Water			
Measurement (unit)	**A**	**B**	**C**
Heterotrophic bacteria count (CFU/mL)	10/1000	10/100	1000/10
Endotoxin (units per mL)	0.03	0.25	n/a

Here are some additional definitions of the parameters they use to indicate the water's purity.

Resistivity – the tendency of water without ions to resist conducting electricity.

The unit of measure is megohm-centimeter (MΩ.cm), often shortened to MΩ or "meg". It is generally used for high purity water. The theoretical maximum is 18.2 MΩ.cm at 25 °C. The higher the ionic content – the lower the resistivity and the lower the ionic content – the higher the resistivity (high resistivity is good!). In ultrapure water systems this value is determined using an in-line meter. Conductivity and resistivity measurements are inversely related to each other.

Conductivity – the tendency of water that contains ions to conduct electricity.

The unit of measure is microsiemens/centimeter (µS/cm) or microhm/cm. The measurement is used to measure feed water or lower quality treated water. The more ions present in the water, the higher the conductivity. This is measured by a conductivity meter.

Total Organic Carbon (TOC) – a measure of the organic contaminants found in water.

The unit of measure is parts per million (ppm) or parts per billion (ppb). Feed water can be in the 2-5 ppm range and the best high purity water should be in the 1-5 ppb range. Measurement of TOC is done using an in-line system.

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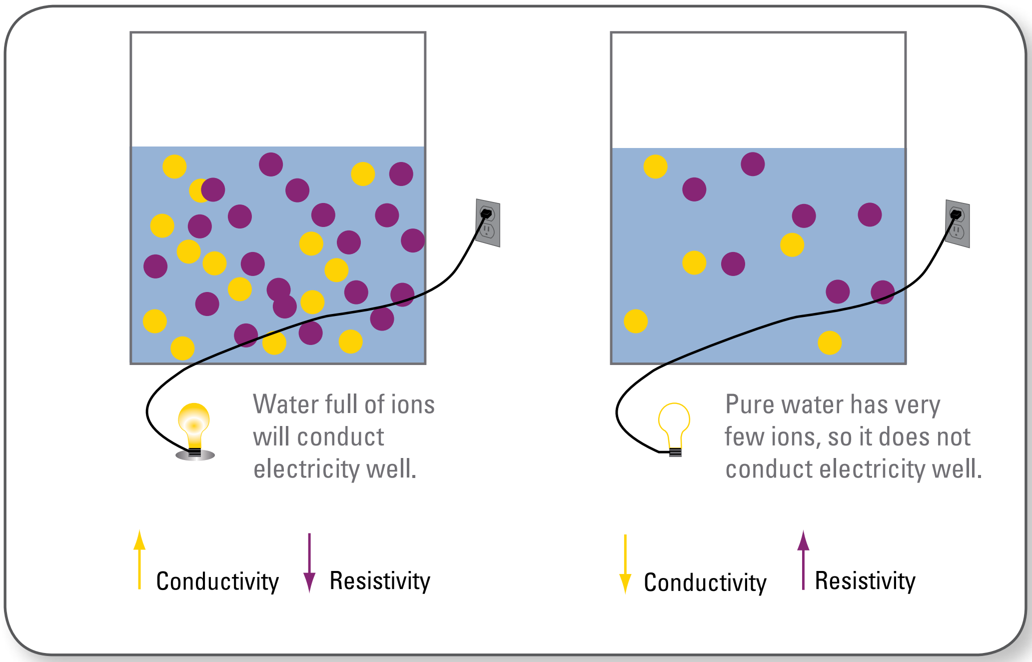
Speaking the language of Lab Water - Advanced technology used to monitor purity



Conductivity and Resistivity

Electrical conductance or resistance is measured by two in-line electrodes. Electrical current moves through water using ionic molecules as stepping stones. The fewer stepping stones, the more difficult the passage of electricity. This causes less electrical conductance and more electrical resistance. The temperature of the water also affects the conductivity/resistivity so readings are usually normalized to 25 °C via temperature compensation.

We use resistivity to measure ion concentration in pure water. We understand water and realize that in order to achieve Type 1 water, meeting the most stringent requirements of our customers, multiple technologies must be used.

Find out more at **thermofisher.com/purewater**

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