Nuclear Power

Nuclear-Grade Products, On-Site Technical Services and Auditing

Purolite works to ensure your plant's chemistry operates at the highest efficiency with quality ion exchange resin.

Purolite®
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About Purolite

Purolite is a leading manufacturer of ion exchange, catalyst, adsorbent and specialty resins. With global headquarters in the United States of America, Purolite is the only company that focuses 100% of its resources on the development and production of resin technology.

Responding to our customers' needs, Purolite has the widest variety of products and the industry's largest technical sales force. Globally, we have strategically located research and development centers and application laboratories. Our ISO 9001 certified manufacturing facilities in the USA, United Kingdom, Romania and China combined with more than 40 sales offices in 30 countries ensure complete worldwide coverage.

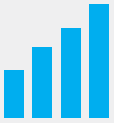
Purolite has been part of Ecolab since 2021. A trusted partner at nearly three million commercial customer locations, Ecolab (ECL) is the global leader in water, hygiene and infection prevention solutions and services. Ecolab delivers comprehensive solutions, data-driven insights and personalized service to advance food safety, maintain clean and safe environments, optimize water and energy use, and improve operational efficiencies and sustainability for customers in the food, healthcare, hospitality and industrial markets in more than 170 countries around the world.

PREMIER PRODUCTS

The quality and consistency of our products are fundamental to our performance. Throughout all Purolite plants, production is carefully controlled to ensure that our products meet the most stringent criteria, regardless of where they are produced.

RELIABLE SERVICE

We are technical experts and problem solvers. Reliable and well-trained, we understand the urgency required to keep businesses operating smoothly. Purolite employs the largest technical sales team in the industry.



INNOVATIVE SOLUTIONS

Our continued investment in research and development means we are always perfecting and discovering innovative uses for ion exchange resins and adsorbents. We strive to make the impossible possible.

Nuclear Grade Resin Technology: Products, Services and Expertise

Contents

Meeting the Nuclear Promise

Purolite works to ensure your plant's chemistry operates at the highest efficiency with quality ion exchange resin. We have been leading the industry for more than 35 years with technical experts that provide on-site services, expertise and auditing to:

Protect your nuclear system against corrosion

- Extend the unit's life
- Maintain a safe environment from radioactive isotopes
- Meet the nuclear promise to help control operating cost

CriticalResin™ is designed exclusively for use in the nuclear power operations and backed by a full-service technical support team. Purolite's diverse NRW nuclear grade product line meets the highest published quality specifications required by nuclear power industry worldwide. It allows power plants to address all areas of water purification within nuclear operations.

FIGURE 1

Provides a perspective on colloid sizes in relation to pore sizes used for filtering.

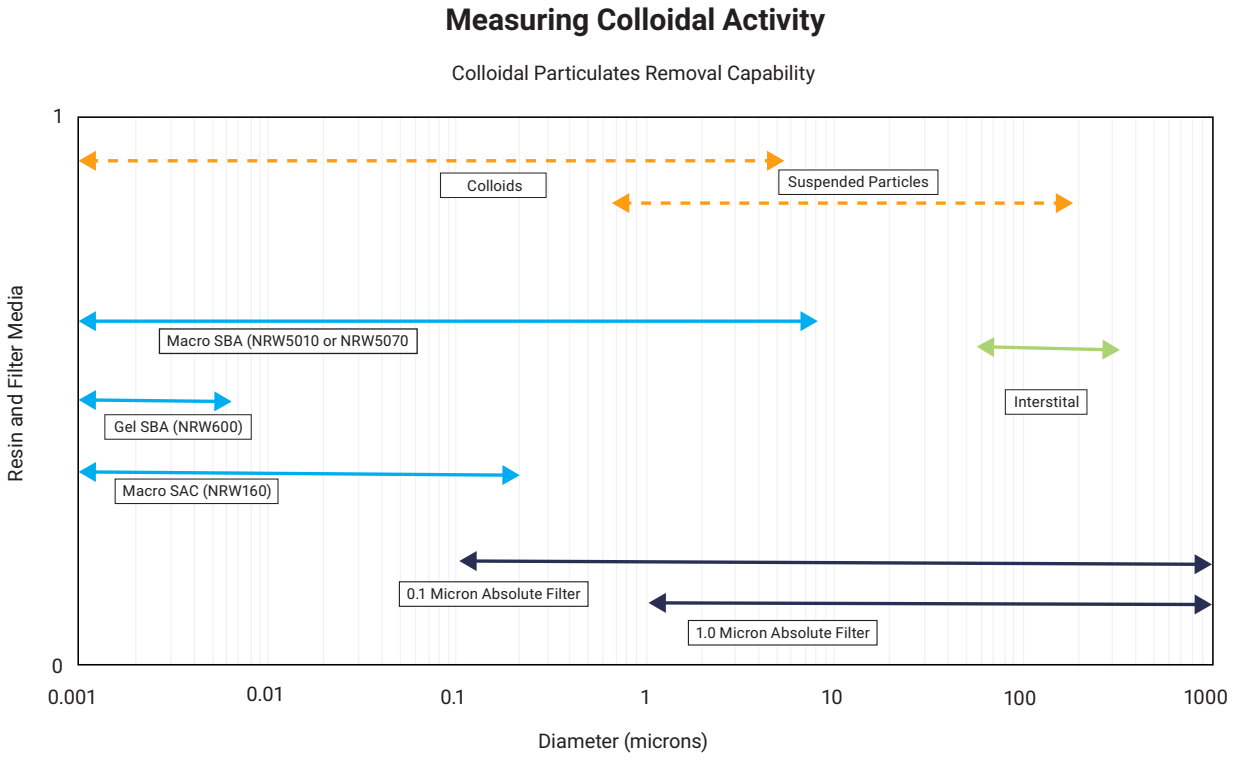
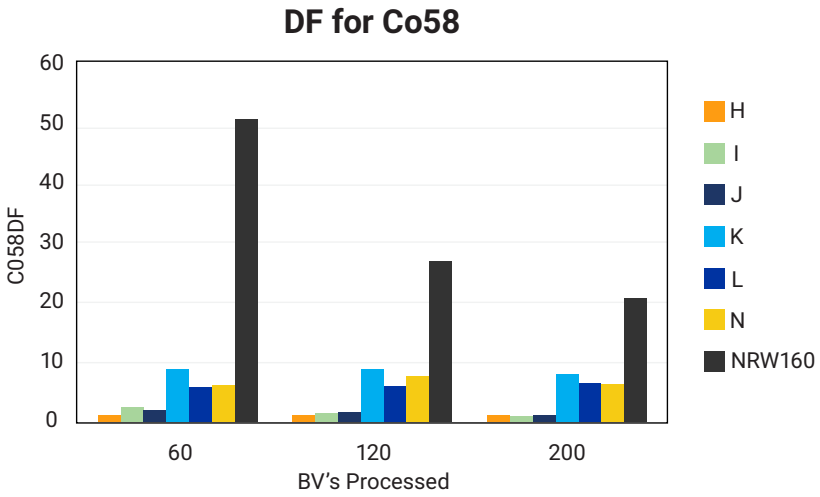


FIGURE 2

Demonstrates that the DF is a relative measurement based on radioactivity removal. NRW160 achieved a higher removal rate through the test period of the cation resins tested in this study.



Nuclear-Grade Resin Applications

Purolite has products to support your reactors for optimal efficiency.

Chemical Volume Control (CVCS) During Full Power

Resin layering technology in the CVCS uses proven macroporous specialty resins, including the orthoporous NRW5010XLC or NRW5070XLC for colloidal activity. The macroporous cation NRW160Li7 for high selective removal of metals including Cs, Co and Ni and the specialty mixed bed NRW3560XLCLi7 for final polishing. This technology has a 20+ year record of exceptional results. The XLC version of the anions ensures no ionic chloride issue during PWR startup with high boron and lithium concentrations.

Outage Cleanup With High Ionic Loads and Fine Colloids

The layered technology discussed above was introduced by Purolite primarily for outage beds, where the greatest colloid and ionic load is generated during the oxidizing cleanup phase. The cleanup bed has an affinity for fine colloids and high selectivity for Co58. With continuous use, this technology is included in the nuclear industry's best practices for source term reduction.

Spent Fuel Pool (SFP) Cleanup

Resins polishing spent fuel coolant encounter aggressive oxidative conditions resulting in sulfate accumulation after a short service period. The high crosslinked cation NRW1180 or the mixed bed NRW3860 incorporating this cation have shown extended life in this environment. Use of these resins and possible other practices such as short loading may improve demineralizer life and reduce resin waste. If difficult isotopes are present in the pool, selective resins such as NRW5330B, with a high affinity for antimony and other trace metals, are available.

Steam Generator Blowdown (SGBD) Recovery

Specific resins have been developed for use in polishing steam generator blowdown for reuse. Our low sodium cations NRW160LS and NRW1160LS are specific for plants that do not regenerate and will operate polishing demineralizers months beyond a conductivity or amine break while controlling the release of Na. The complimenting mixed beds NRW3560LS and NRW3675LS also employ low sodium cation components supporting long-term service of the blowdown demineralizer. If resins are regenerated or operated in other configurations, many resins are available to complement your system operation.

Radioactive Waste Cleanup

Removal of isotopes and ionic impurities from waters planned for reuse, as in BWRs, or discharge is properly addressed with the specialty mixed bed NRW3560 or the slightly more economical mixed bed NRW3240. The layered specialty macroporous anion NRW5010 or NRW5070 and the macroporous cation NRW160 during outage cleanup generally improve the treatability of wastewater collected during an outage. If there are difficult isotopes in the radwaste stream, many selective resins are available for specific situations.

Nuclear Grade Resin For Deep Bed Condensate Polishing (CP)

Specialty condensate polishing resins Supergel™ SGC650H and Supergel SGA550OH or the premix mixed bed NRW1200 are designed for PWR polishers. For those preferring visual benefits and fouling tolerance of macroporous anions, NRW5050 is a proven product. Non-regenerable pressurized water reactor (PWR) and boiling water reactor (BWR) deep bed polishers will find NRW1160 and NRW8000 beneficial with these low organic sulfate and organic chloride releasing resins. Those BWRs and PWRs using precoat filter demineralizers will use the Purolite Microlite MB1:1H to meet polishing objectives effectively.

Polishing Requirements for Makeup (MU) Water

Regenerable resins such as NRW100 and NRW400 will perform the bulk of the demineralization and mixed bed polishing followed by a non-regenerable mixed bed UCW3710 for final polishing of trace ions and minimizing total organic carbon (TOC) release from the resin. This makeup water will be used in all nuclear systems.

Nuclear Grade Resin for Reactor Water Cleanup (RWC)

The layered technology discussed above is applicable for BWR reactor water demineralizers with an affinity for fine colloids and excellent selectivity for Co60. Those plants with precoat filter demineralizers will find CG19H effective as a standalone precoat or an underlay for the cobalt selective precoat CoSeq73.

Supporting Reactors

Pressurized Water Reactors

CriticalResin can notably improve pressurized water reactor circuits boosting throughput and de-contamination without sacrificing quality. Purolite has a diverse product line to support all nuclear systems, such as:

- Primary Circuit Treatment
- Secondary Circuit Treatment
- Deboration
- Fuel Pool
- Radiation Waste

The pressurized water reactor (PWR) is the most widely used nuclear power generation design and has achieved great success worldwide. This reactor design has a pressurized primary circuit coolant heated by the reactor core. The water circulates to a steam generator, transferring heat to a secondary water system. This secondary system generates steam at 500F and 900 PSIG that drives a steam turbine to generate electricity. The advantage of this reactor type is that the radioactive sections (the reactor and primary circuit) are separate from the rest of the power plant. Such separation helps to control and minimize potential contamination risks.

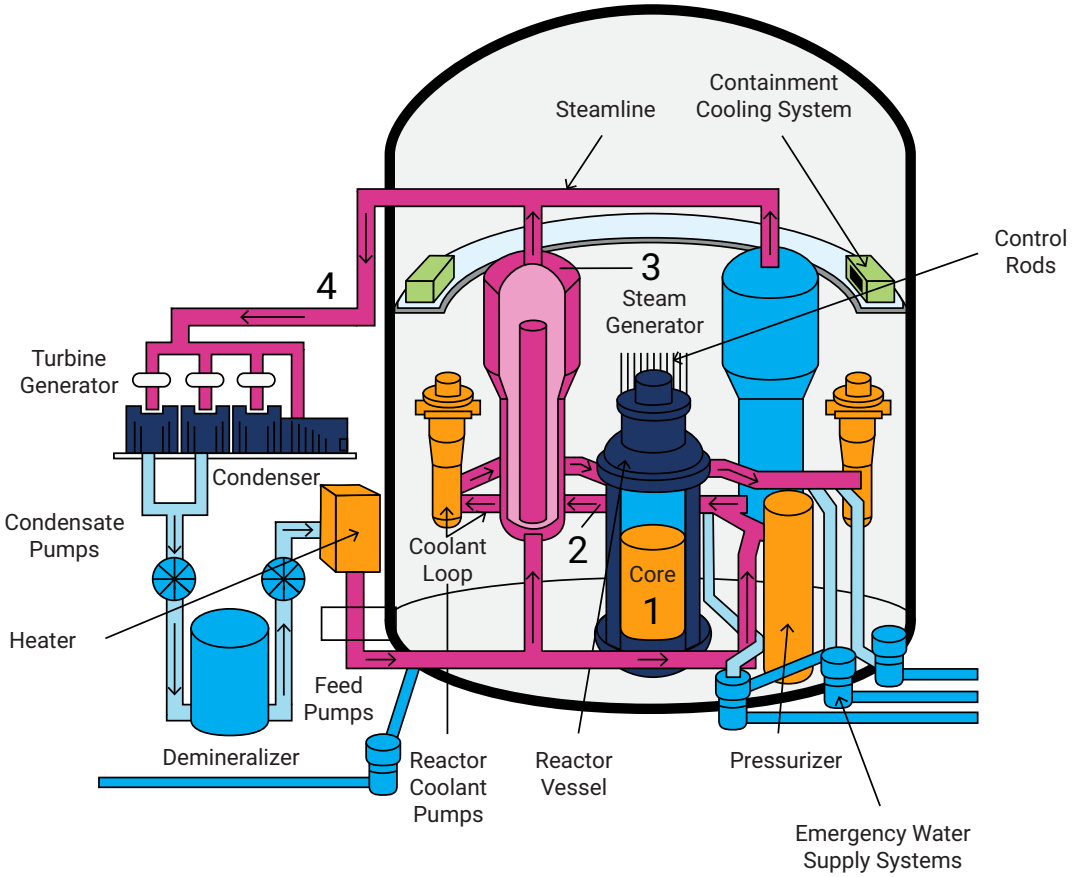
The primary circuit water is directly connected with the reactor fuel, where it is both a coolant and moderator. This Primary circuit water transports heat from the fuel bundles to the steam generator, which cools the fuel while reducing neutron movement with boron and fuel rods, further controlling fuel temperature. When exposed to the core, impurities from the makeup water and corrosion products in the coolant become radioactive, contributing to source term within the system and forming deposits on the fuel bundles. This primary coolant must be clean and free of soluble and suspended corrosion matter to protect the fuel rods and the safety of workers in the plant.

Operators must control the level of inorganic salts (sodium, sulfate, and chloride), which supports corrosion in the granular structure of the fuel rod sheaths and system metal surfaces. Two types can occur — intergranular corrosion (IGC) or stress corrosion cracking (SCC). Corrosion by-products will foul fuel and contribute to irregular burning, known as axial anomalies or crud-induced power shift (CIPS). These corrosion by-products will become activated isotopes released as crud bursts during cool-down periods of outages. These buildups and releases can damage fuel sheaths and contribute to fuel leaks.

PWRs use enriched UO2 (between 2.0 and 4.95 wt.%) in pellet form as fuel. In a 900 MW power plant, the reactor uses up to 72 tons of uranium annually. These pellets are contained inside zirconium alloy sheaths (zircaloy) to form a rod. Approximately 200 of these fuel rods in a typical design create a bundle or element. A reactor core can contain 150 to 200-rod bundles that are arranged for optimum heat generation.

FIGURE 3

Pressurized Water Reactors (PWR) Basic Design



Boiler Water Reactor

The boiler water reactor (BWR) is the second most widely used type of light-water reactor. This reactor uses the highest purity water in the coolant circuit, which is used to supply steam directly from the fuel bundles to turbines. The moderator and coolant water temperature reach 286 °C at the core. The water is maintained at a pressure of only 70 bars (1000 psig), where it is transformed into steam. Highest purity water is required as the BWR serves as a steam generator, which means the whole circuit is radioactive. Salts and corrosion products contribute to source term and impact safety conditions in the plant.

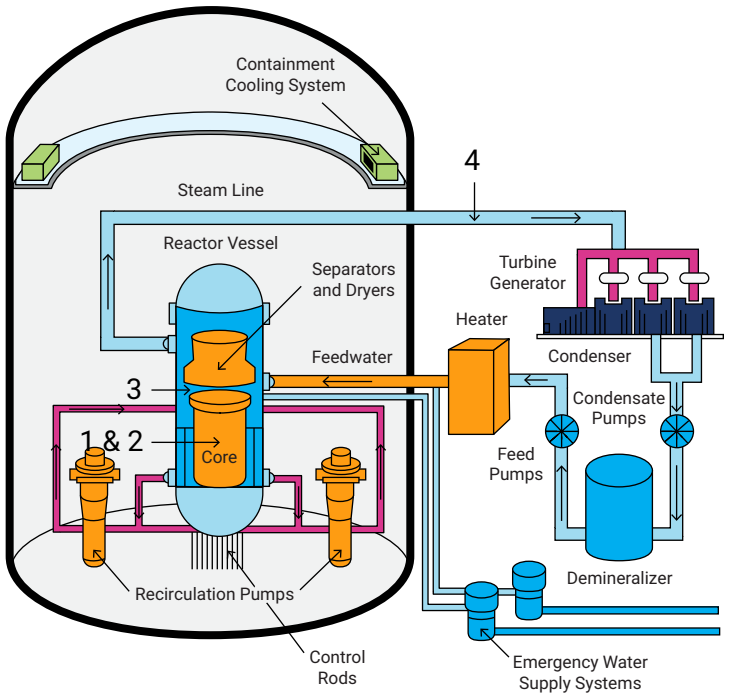
The fuel used in the BWR is similar to that used for a pressurized water reactor (PWR), but the fuel rods have a larger diameter, and the bundles only contain about 50 sheaths.

Resin products and water treatment systems used in a BWR are a bit different from the PWR. The highest purity water filter demineralizer systems are used to polish the reactor coolant and the return condensate. Filter demineralizers contain filter elements that are precoated with finely ground ion exchange resins that mix cation and anion resin with fiber, sometimes used to improve filtration. BWRs with freshwater cooling will likely use only the filter demineralizers for purification. However, plants with brackish or saltwater cooling will also have deep bed condensate polishing employing the whole bead mixed bed resins, providing greater protection to the system.

Purolite has a full line of CriticalResin to address the BWR reactor water and condensate systems, fuel pool, suppression pool, and radwaste purification.

FIGURE 4

Boiling Water Reactor Configuration



Advanced Small Modular Reactors (SMR)

Purolite experts understand how SMRs present an excellent opportunity to provide safe, clean and affordable nuclear power production. With their smaller footprint, reduced investment and reactors' ability to be placed in locations not possible for more extensive nuclear plants, we recognize that SMRs produce excellent power generation, process heat, desalination, and other meaningful industrial uses. Our team can support a variety of SMR sizes, technology options, capabilities and deployment scenarios.

Fast Breeder Reactors

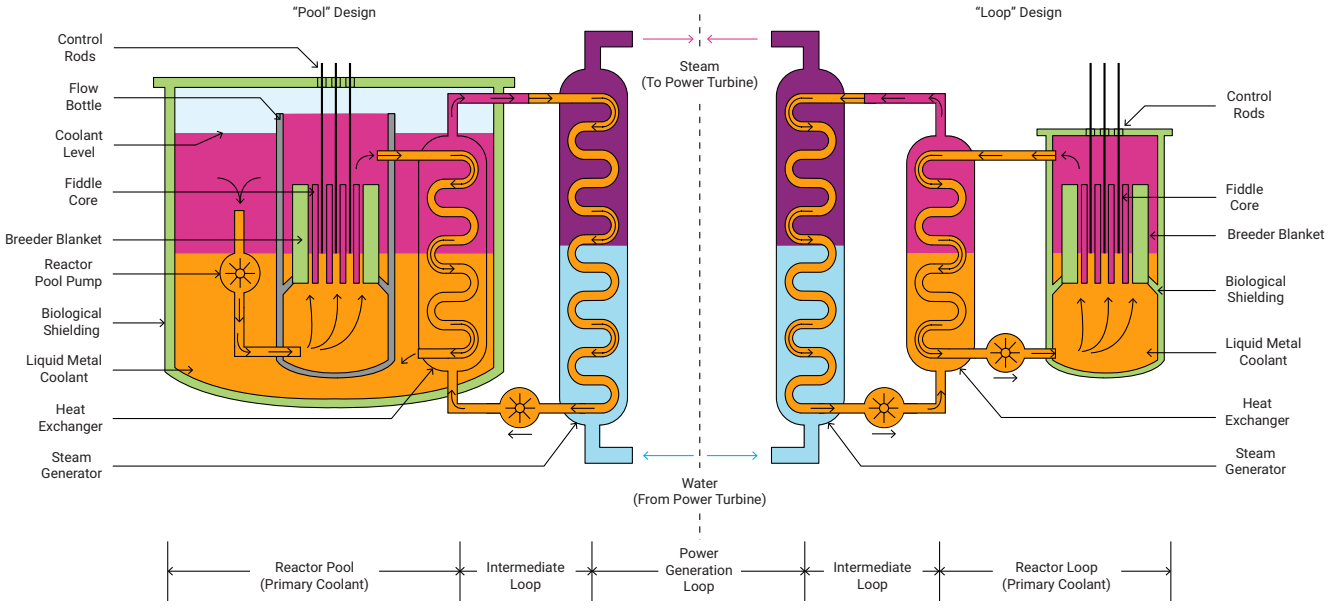
In a fast breeder reactor, also known as a liquid metal fast breeder reactor (LMFBR), splitting atoms generates more fissionable material (fissile) than it consumes. Breeders use mixed oxide fuels (MOX) primarily composed of 238U and other minor actinides. The typical design of the fast breeder begins with the center of the reactor core coated with impoverished uranium (238U).

The initial fuel, 235U, harnesses the fast neutrons emitted by the impoverished 238U and becomes 239Pu. Active isotope production rods get replaced approximately every week, and 239Pu extracted is used once more in the same or another power plant.

Coolant in an LMFBR (commonly liquid sodium) operates at a temperature of approximately 600 ºC, with the reactor enclosed in a concrete protection shield. The liquid metal coolant does not limit the neutron energy from 235U. Unlike a pressurized water reactor (PWR) or boiling water reactor (BWR), which uses water as a moderator, the neutrons emitted by the fission of active nuclei are not slowed down.

FIGURE 5

Liquid Metal Cooled Fast Breeder Reactor



Water-Water Energetic Reactor (WWER or VVER)

Designed by the Soviet Union, this type of pressurized water reactor (PWR) ranges from generation I reactors to modern generation III+. It employs light water as a coolant and a moderator. With the use of horizontal steam generators, hexagonal fuel assemblies, no bottom penetrations in the pressure vessel and high-capacity pressurizers, this reactor is widely used in Europe, China and Russia.

Purolite experts understand how VVERs presents an excellent opportunity to provide safe, clean and affordable nuclear power production. Our team can support a variety of VVER designs.

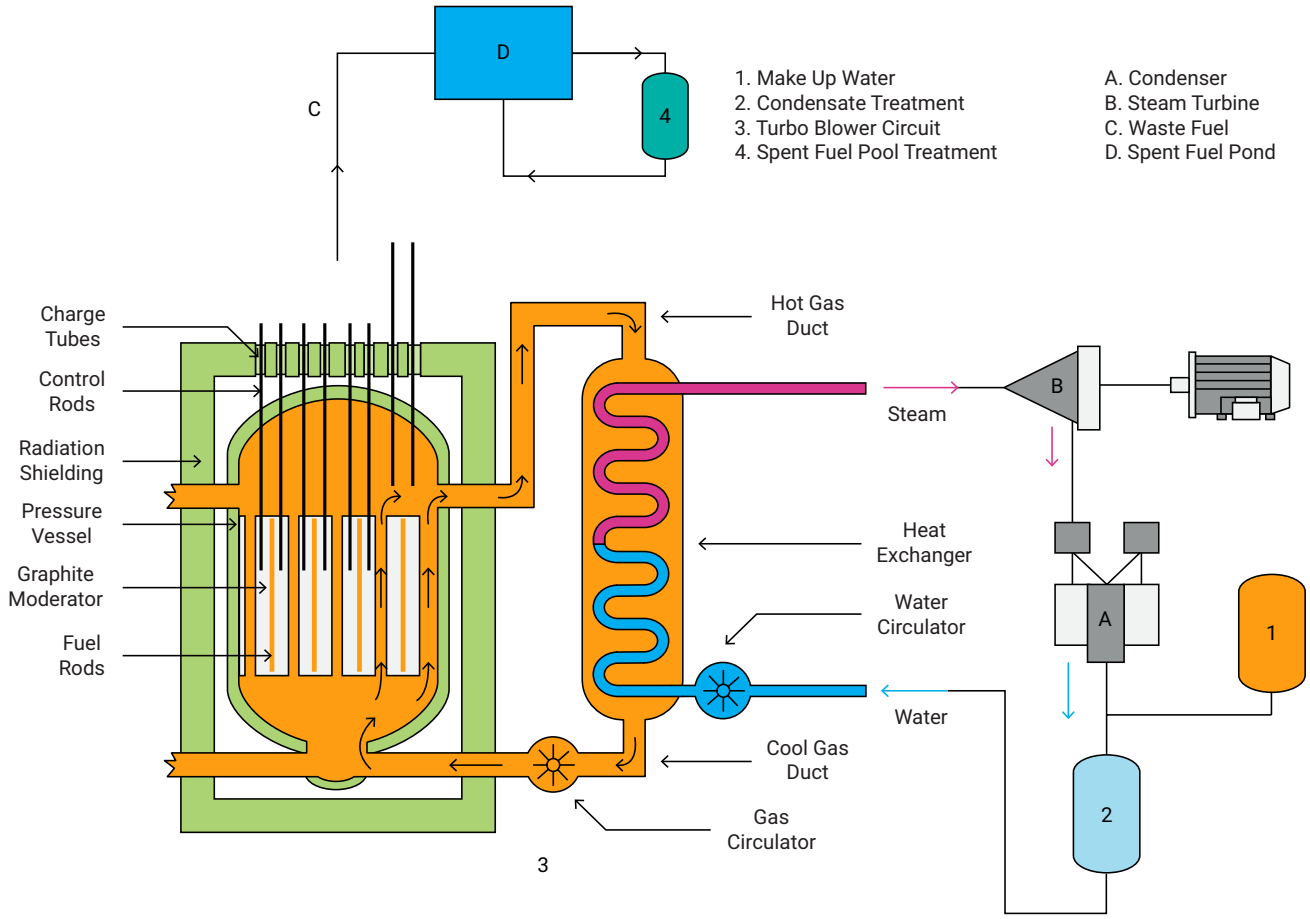
Graphite-Gas Reactors

The graphite-gas reactor was one of the first types to be introduced. Initial designs included the Magnox and the advanced gas-cooled reactor (AGR) system. All these operate with two reactors in a single structure and use uranium as the fuel. In the reactor core, fuel rods inside a graphite block act as a moderator.

The coolant is pressurized CO2, which passes through the reactor core, removing heat. This heated CO2 stream drives turbine generators that generate electricity. One of the primary advantages of the graphite-gas design is its ability to allow for the online replacement of fuel elements. Operating difficulties make graphite-gas reactors commercially less attractive to build and have restricted widespread use of this design. Ion exchange technology treats four circuits in a graphite-gas nuclear plant. They are the makeup water, the returned condensate, the turbo blower and the spent fuel pool.

FIGURE 6

Gas-Graphite Reactor — Ion Exchange Treatment Circuits



CriticalResin for Nuclear Power

CriticalResin products are nuclear-grade ion exchange resins designed exclusively for use in nuclear power operations and backed by a full-service technical support team.

Purolite's diverse CriticalResin product line meets the highest published quality specifications required by the nuclear power industry and allows power plants to address all areas of water purification within nuclear operations.

Ion exchange resins, in bead and powder form, are used extensively in all types of nuclear power plants worldwide. Ion exchange systems are the most cost-effective and, in some cases, the only way to produce water with the quality required for proper plant operation.

TABLE 1

Application	Product Number(s)
Cation Conductivity	NRW160IND
Colloidal Removal	NRW5010, NRW5010XLC, NRW5070, NRW5070XLC
Condensate Polishing, Anion Underlay	NRW6000, NRW600XLC, NRW8000
Condensate Polishing, Precoat	CG19H
Condensate Polishing, Primary Water	NRW3560, NRW3560LS, NRW3560XLCL17, NRW3561, NRW3640, NRW3675LS
Condensate Polishing, Secondary Water	NRW6000, NRW1100
CVCS, Clean Up Bed	NRW3460, NRW3560, NRW3670
CVCS, Delithiantion Bed	NRW1160, NRW1160LS, NRW160, NRW160LS
CVCS, Lithiated Polishing Bed	NRW3460Li7, NRW3560Li7, NRW3560XLCLi7, NRW160Li7
Radwaste Cleanup	NRW100, NRW1180, NRW3460, NRW3560, NRW600, NRW8000
Spent Fuel Pool	NRW160, NRW3560, NRW3560XLC, NRW5330B, NRW600
Steam Generator Blowdown	NRW1160, NRW1160LS, NRW160, NRW160LS, NRW3560, NRW3560LS, NRW3675LS

Notes

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Purolite, the leading manufacturer of quality ion exchange, catalyst, adsorbent and specialty high-performance resins, is the only company that focuses 100% of its resources on the development and production of resin technology.

We're ready to solve your process challenges. For further information on Purolite products and services, visit www.purolite.com or contact your nearest Technical Sales Office.

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