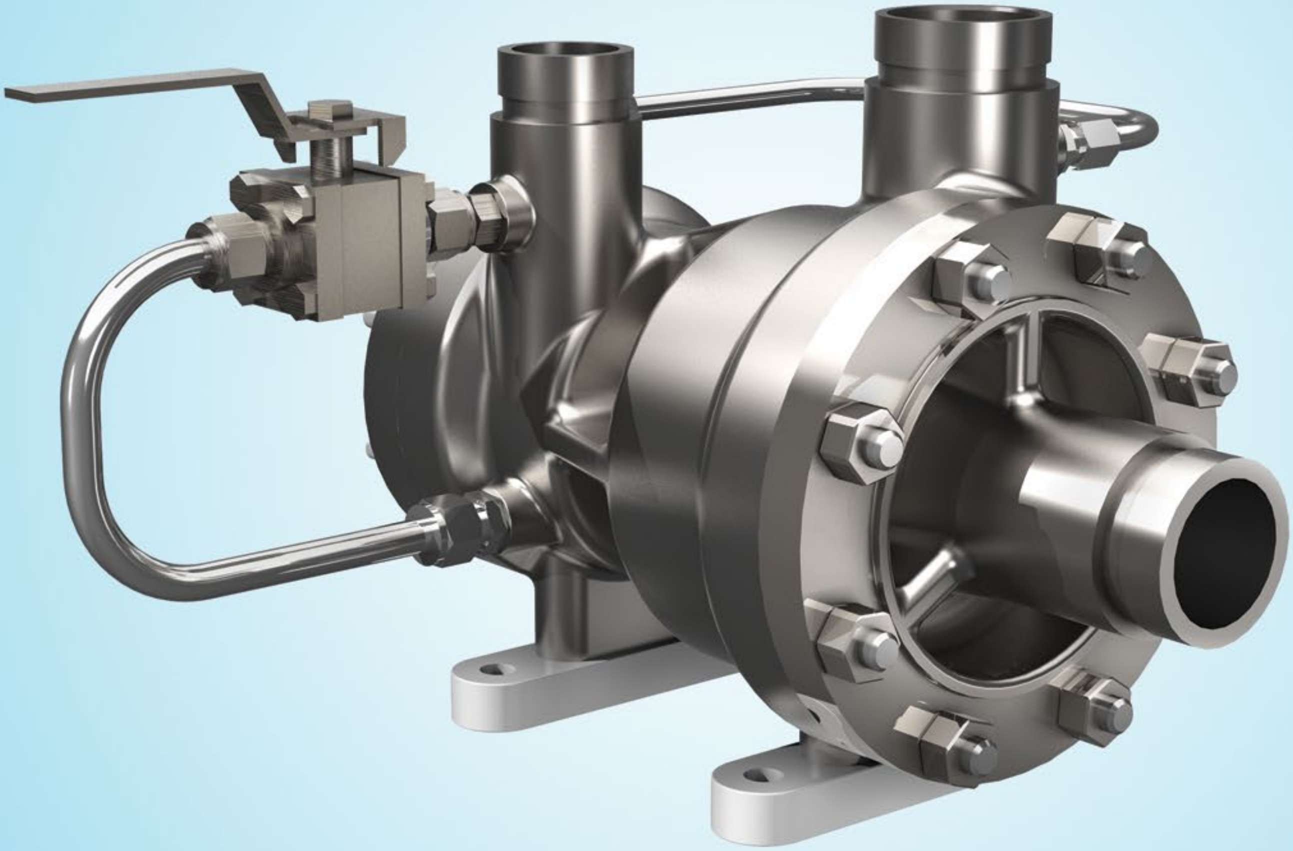

Enhanced Turbocharger Design in Desalination

energy recovery™

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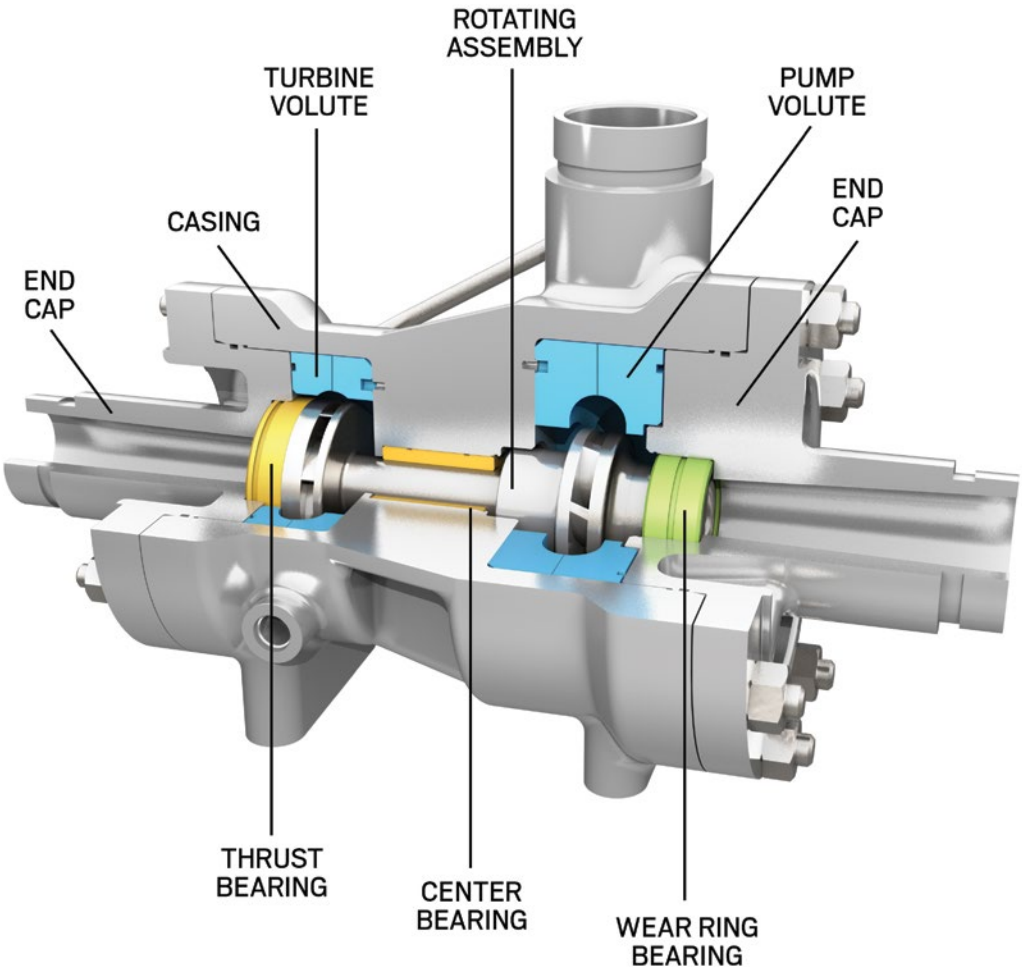
The Need for Energy Savings in Desalination



A cutaway of the AT Turbocharger shows the solution's single rotating assembly and removable volutes

The number of desalination plants around the world has skyrocketed in the past decade. In June 2015, the International Desalination Association (IDA) tallied more than 18,000 desal plants operating worldwide, and some estimates put the total number above 20,000. By comparison, only a few thousand plants were in operation at the turn of the millennium, and there was almost no desalination infrastructure dating back before the 1970s.

As the demand for potable water has surged, so has the demand for more desalination plants of various sizes, especially in drought-parched coastal regions with high population density, agricultural commerce, and other water-reliant industries.

Desalination mega-plants have grabbed headlines for their ability to produce more than 50,000 cubic meters of water daily (13 million gallons per day) and offer a sustainable solution to freshwater shortages. While technology has evolved to serve massive oceanfront facilities, innovation is available to plants of all sizes and types, including high-pressure saltwater and low-pressure brackish water processing plants. Smaller-scale but vitally important desalination plants can be found on a variety of islands, in and near inland cities in desert regions and drier climates, on large freight and cruise ships, on off-shore oil platforms, and near coastal and interior military bases, to name just a few settings.

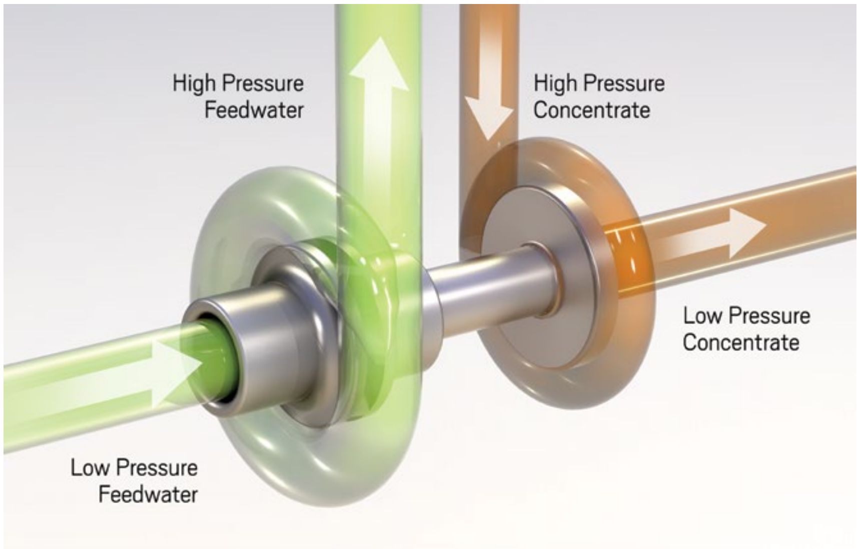
No matter where they are located or what purpose they serve, smaller reverse osmosis (RO) and seawater reverse osmosis (SWRO) plants tend to have one defining feature in common, besides the desalination solution offered: they suffer from profit and productivity loss during downtime. In the worst cases, repairs and parts replacements can take a plant offline for several weeks. But even small changes to large systems can have a sizable impact, especially over many months, years, or the life cycle of a facility.

Identifying impactful but lower-investment solutions shouldn't be the biggest burden plant operators have to overcome. Operators should be free to focus on identifying and implementing the most effective ways to save energy up front, as well as methods to feed that saved energy back into the system rather than letting it go to waste.

How Turbocharger Technology Serves Desalination

Energy Recovery, Inc. offers precision turbocharger technology that lowers energy consumption by 20 to 30 percent. This translates to substantial savings for lower-investment solutions, especially in locations where power costs are heavily subsidized or there is a need to mitigate up-front capital or equipment costs.

Energy Recovery's AT Turbocharger simplifies any SWRO system and is suitable for use in high-pressure seawater and low-pressure brackish water systems. The device is lightweight, is easy to install, has a compact footprint, and does not require any ancillary equipment. The high-performance turbocharger can handle 50 to 10,000+ gallons per minute (11 to 2,272 m3/hr) and pressures from 600 to 1,200 psi (45 to 80 bar).



Pressure energy is recovered by the AT Turbocharger through a fluid-to-fluid transfer of energy, from high pressure brine to the low pressure feedwater

The AT Turbocharger reduces the amount of pressure the high-pressure pump must create. In a way, it acts as a second pump, powered by a hydraulic turbine rather than a traditional electric motor. As with all turbochargers, the heart of the system includes a pump and turbine connected to a common shaft. Hydraulic energy from the concentrate stream is captured by the turbine impeller and converted to mechanical energy. The pump impeller then converts the mechanical energy back to hydraulic energy, offering an additional energy boost.

Currently, Energy Recovery has more than 3,000 turbochargers installed all over the world.

Improvements to the AT Turbocharger

The new AT turbocharger features several new design elements to further improve durability, reliability, and availability. At Energy Recovery, we studied experiences from customers and more than 3,000 turbocharger installations around the globe to see how we could innovate on our already proven solution. The result is an evolved turbocharger that is even more durable and less likely to fail.

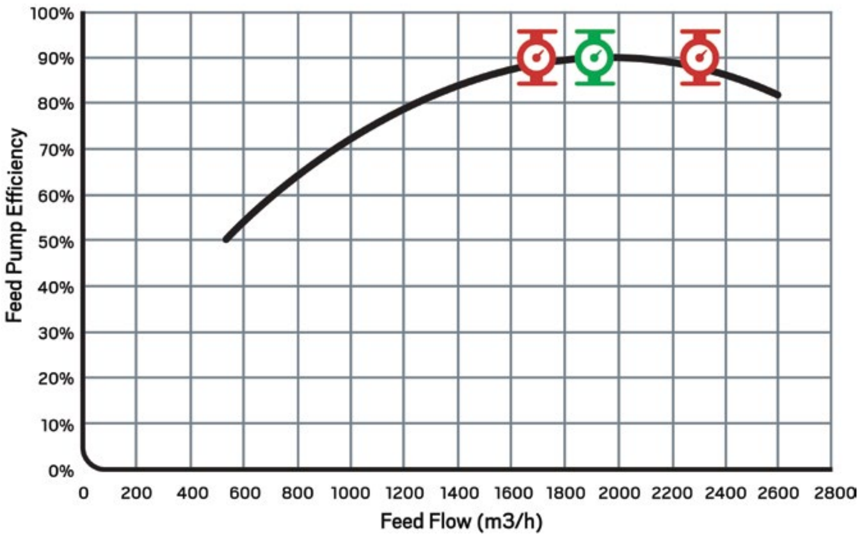
Building on the existing turbocharger design, Energy Recovery's engineers developed modifications to increase online time at plants. The new design is more resilient and protects the internals against system upsets. This results in fewer failures of potentially costly and hard-to-replace parts. In the event of a system upset and subsequent failure, parts can be replaced more easily and plants can cut back on expensive offline time needed for repairs. The new design significantly reduces downtime and provides plant operators with major savings over the life of the plant.

The new AT Turbocharger offers the same easily installed solution. The improvements require minimal installation time and operator training and work within plant design—no major system overhaul or expensive reconfiguration is needed. In addition to their improving the overall performance of the turbocharger, there is no need for ancillary support or additional equipment to install or maintain.

Replaceable Volute Inserts to Accommodate Flexible Conditions

Historically, centrifugal-type energy recovery devices were sized for optimal efficiency at a single operating point. To optimize the design for specific operating conditions, a volute would be customized for a specific plant and then machined directly into the case of the turbocharger itself. Machining volutes into steel, especially 2205 Duplex Stainless Steel, is a slow, labor-intensive process requiring many machine passes and multiple high-strength tools. Once a volute is cast and machined, it is extremely difficult to adapt to variations in operating conditions.

Cast and machined stainless steel volutes cannot accommodate changes in pump flows and pressures in the most efficient and cost-effective way. Energy Recovery's innovative design method uses a plastic polymer insert for the fluid pathways. This has the added benefit of allowing the user to store several sets of these low-cost volute inserts so that when operating conditions change, the equipment efficiency is restored with minimal downtime and cost to the operator. This provides a viable solution to operators who previously could not adapt to changing operating conditions with other technologies that had one hydraulic design machined into the stainless steel casing.



With replaceable volutes, the AT Turbocharger can accommodate flexible flow rates, which can translate into millions of dollars saved in operating expenses

It's also important to note that over the life of a plant, pressures can vary significantly because of changes in salinity and temperature and improvements in membrane technology. At these different pressures, any turbocharger will operate off its best efficiency point. This can result in an efficiency loss of approximately 2 to 5 percent—and perhaps more in some cases. While a few percentage points may not seem significant, in systems that process more than 10 million gallons per day (MGD) (37,854.12 m3/day), and with an eye to ever-increasing energy prices, this can equate to millions of dollars in additional operating expenses.

This is just one example of a seemingly slight modification that offers considerable energy and cost savings over time. The new AT Turbocharger upgrades prevent efficiency losses from changing operating conditions, so plant operations can recover a significant amount of energy from the desalination process and transfer that energy back to the seawater RO feed stream.

Upgraded Thrust Bearing Material

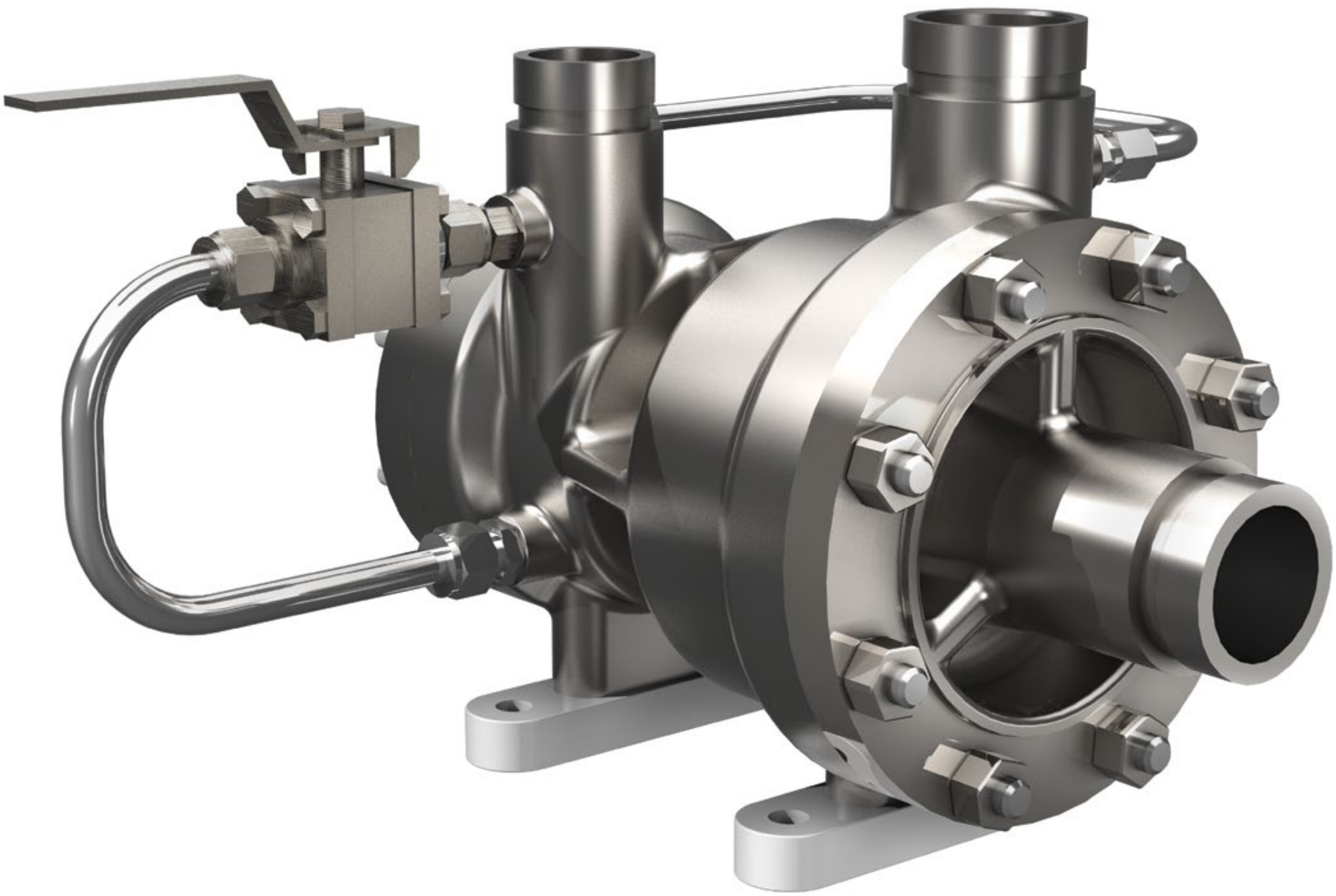
Turbocharger thrust bearings traditionally have been made of carbon graphite (CG). The problem with CG is that it is extremely hard and brittle. If a piece is chipped or broken off, very hard debris is introduced into the fluid film layer. This debris will continue to circulate in the bearing groove and eventually destroy the bearing.

When a traditional CG thrust bearing fails, it damages the turbine face of the rotating assembly. The rotating assembly is custom engineered for each customer, and repair or replacement can take weeks, resulting in significant downtime. Plant operators can keep a spare rotating assembly on the shelf, but many know those expensive parts are costly backups—the kind of extraneous costs that can severely impact a small plant's operating budget.

Drawing on our enhanced material science expertise, Energy Recovery has selected a higher-grade bearing material. The lightweight material is thermodynamically stable and does not swell or deform under intense pressure. It is easy to handle and not susceptible to corrosion. Most important, if the bearing is damaged, it will not chip and create debris. Instead, it will deform and melt until the fluid film is lost and the turbine face ultimately comes into contact with the bearing. Unlike the CG bearing, which damages the turbine face, our new bearing will not cause significant damage to the point at which the turbine face must be repaired. This results in a more durable and reliable bearing system.

Stronger Rotating Assembly Construction

To produce the rotating assembly for the turbocharger, vanes are traditionally welded to the hub and shroud of the impeller. This technique works, but often turbochargers have very small vane passages. Welding in these passages poses a major challenge for even the most



The casing of Energy Recovery's AT Turbocharger features a removable end cap designed for easy maintenance

gifted welders. When welded incorrectly or in a less than optimal environment, the resulting weld seam can disrupt hydraulic flow or result in bad welds—or both.

Energy Recovery now employs an improved method for fusing together the vanes and the hub and shroud, which produces a smoother and structurally stronger connection than welding can achieve. This process reduces welding slag and fuses the steel more completely together, allowing for maximum hydraulic efficiency and a smoother fluid flow.

Energy Recovery made several other design changes to the turbine impeller and thrust bearing interface that increase reliability and durability and decrease potential for wear and tear against the bearing surface. The new design offers a smoother hydraulic flow path that minimizes energy waste and enhances hydraulic efficiency.

Choosing the Best Technology for the Life of Your Plant

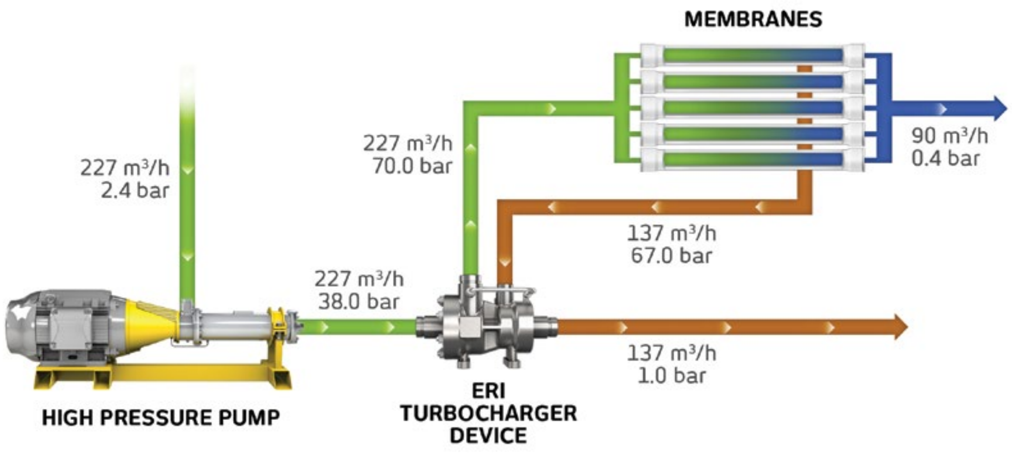
The life-cycle cost of a plant is one of the most important factors to consider when planning and specifying equipment. Over the 20- to 25-year life of a large SWRO facility, the operating cost will tend to exceed the initial capital investment.

The high-pressure equipment installed in a desalination facility has the largest direct effect on a plant's power consumption. When components such as high-pressure pumps and energy-recovery devices are adaptable and flexible to maintain efficiency while keeping costs down, this is the most advantageous scenario for both the designer and the operator.

The equipment life-cycle calculation is critical in choosing the appropriate components for a system. Initial efficiency matters to operators of newer plants, but the key strength of these AT Turbochargers is their long-term adaptability to plant conditions.

Energy Recovery's AT Turbochargers are easy to install and adaptable to many conditional environments. This makes them perfect for installation in newly built facilities or as a replacement solution for existing facilities looking for more energy savings and less unplanned downtime.

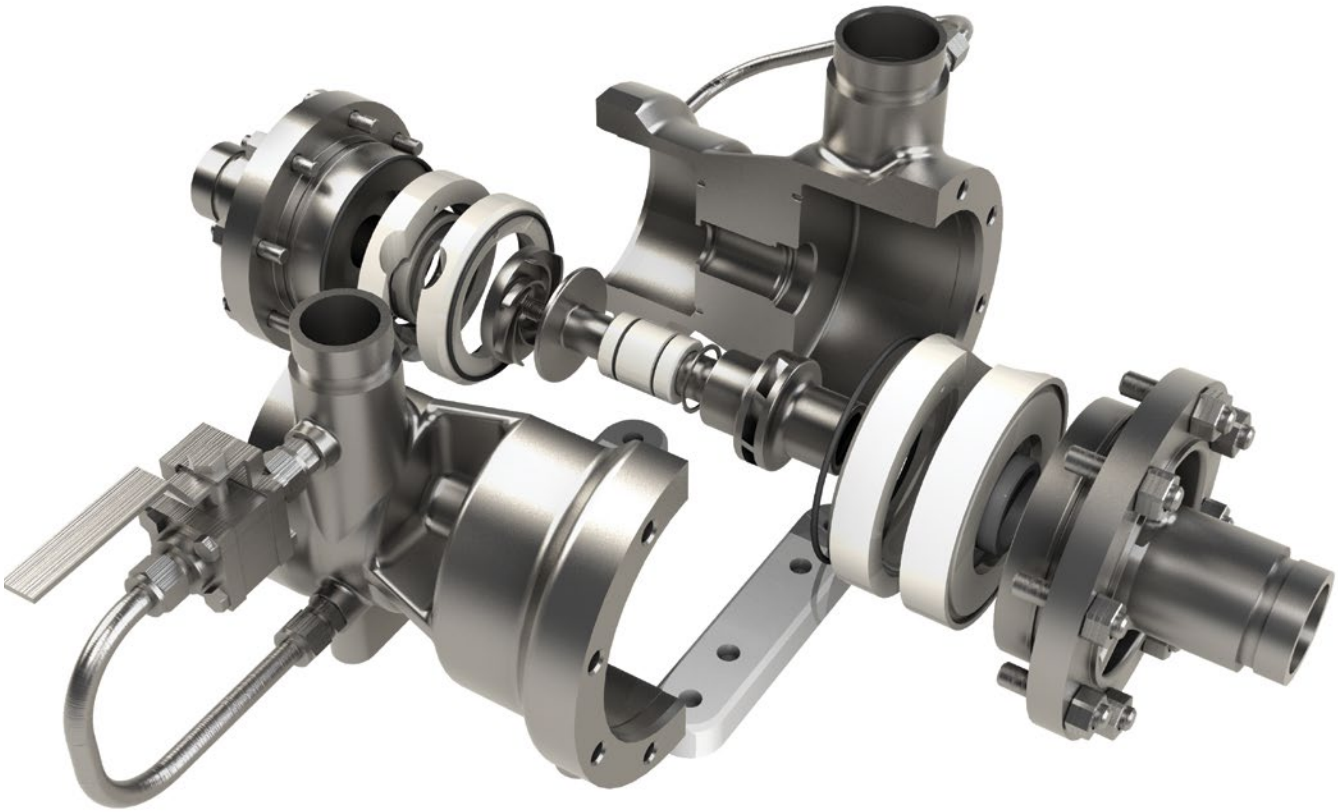
As energy continues to be top of mind and a critical factor in the design and maintenance of a plant, the efficiency of equipment and its ability to maintain optimal efficiency throughout the life of the system are going to be critical factors.



This simplified process flow diagram shows how the Energy Recovery AT Turbocharger fits into the configuration of a typical desalination plant

The recent enhancements to Energy Recovery's AT Turbocharger mean fewer spare components are needed—and that operators need little training to fix minor problems that, by comparison, used to put a plant offline for days or even weeks. This improves an operator's job, and perhaps more crucial, it improves the overall system and keeps a plant online when previously it would have required significant downtime to solve a relatively minor mechanical problem.

No matter the plant's size, type, or age, it's crucial for operators to choose a turbocharger that will continue to be reliable as it adapts to other component or condition changes, such as advances in membrane technology or pretreatment. The turbocharger technology developed by Energy Recovery was designed specifically to meet the needs of plant operators in desalination, and the evolution of the AT Turbocharger design makes our proven technology that much more efficient and reliable.



About Energy Recovery

Energy Recovery (NASDAQ:ERII) develops award-winning solutions that harness unused pressure energy to improve reliability and availability of industrial pumping systems. Our technology protects vulnerable equipment and saves substantial energy and maintenance costs for operators within the oil & gas, chemical, and water industries. With more than 17,000 devices worldwide, our products save clients more than $1.7 billion (USD) annually. Headquartered in the San Francisco Bay Area, Energy Recovery has offices in Shanghai and Dubai.

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