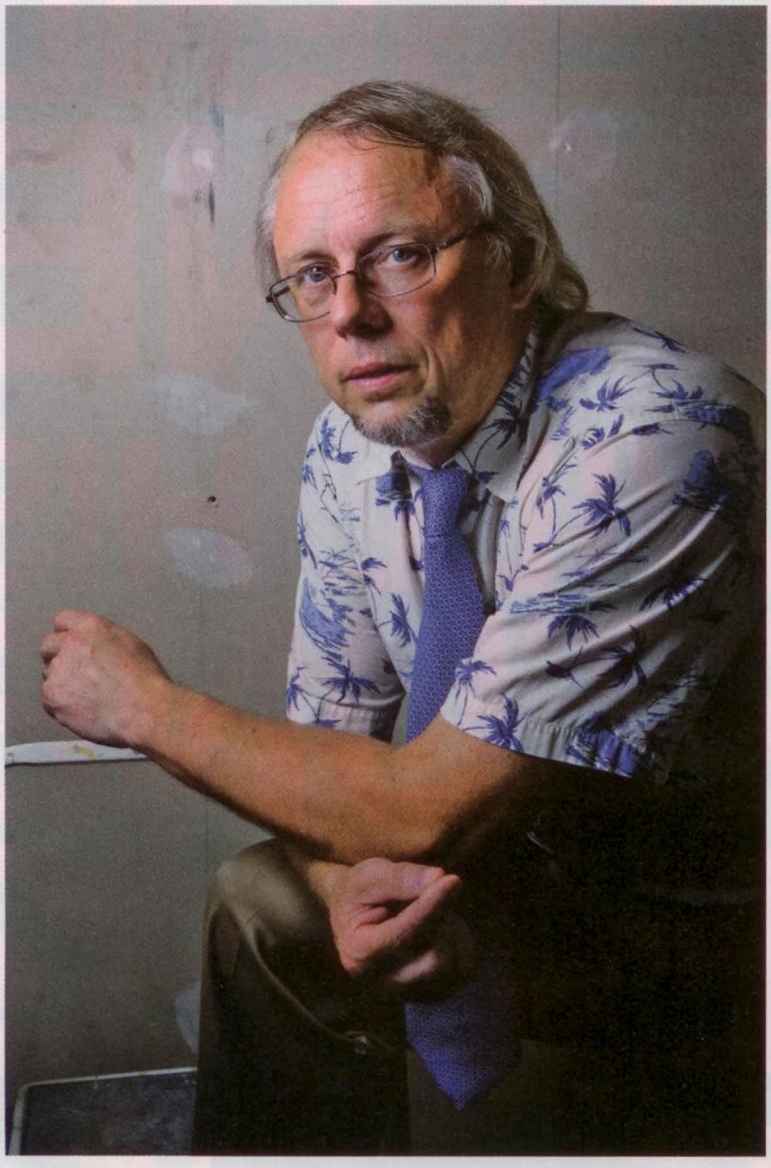


Leif Hauge got his invention to work—but not before his backers got antsy.

The Wizard Of Water

A revolutionary device with one moving part is making desalination cheaper and less energy-hungry around the world. By Jonathan Fahey

IN 1986 LEIF HAUGE'S brother had a farm in Norway near the sea and wanted to keep his vegetables cool by circulating water from deep in an adjacent fjord that would flow through pipes and surround a storage area. It takes a lot of energy to pump water uphill 100 feet, and if you let the water run back down you waste the energy. Was there a way to recover some of the energy? Have the water running down lift the water going up? Leif Hauge set about building a device to do just that. He eventually gave up after figuring his brother didn't have quite enough water pressure to harvest. But he learned a lot about energy recovery.

There is not, as it happens, a big global market for fjord-cooled vegetable storage. But there is need for energy exchangers in desalination plants. These plants extract fresh water by pumping up seawater to extremely high pressure and running it against a membrane that lets water molecules through but not salt ions. The pressurizing consumes gobs of electricity. Simply releasing the spent, high-pressure saltwater back into the sea is a waste of energy. That energy can be recovered in a pressure exchanger. A year after delving into the veggie-cooling project, Hauge realized that a variation on his water pump contraption could compete in the market for pressure exchangers sold to desalination plants.

Hauge, 53, never finished college and has been self-employed his whole life, working in construction and as an inventor. He eventually got his saltwater pressure exchanger to work. But it was a Pyrrhic victory. He consumed so much capital in the quest to perfect the device that he lost control of Energy Recovery Inc., the company he had founded to make the exchangers. The San Leandro, Calif. firm earned $8.7 million on $52 mil-

ASHLEY TWIGGS FOR FORBES

ERI Chief G.G. Pique turned an ingenious invention into profits.

TIMOTHY ARCHIBALD FOR FORBES

lion in sales last year, but Hauge owns none of it and is consulting on water and renewable energy projects in Virginia. Maybe he should have quit? "I don't know why I didn't," he says. "I guess it's my nature. I persevere."

ERI's PX Pressure Exchanger is a 4-foot-long, 180-pound object containing a single moving part: a ceramic cylinder spinning at 1,000rpm as it pumps 13,000 gallons of briny water an hour. The device costs $25,000 and has 70% of the market for desalination energy-recovery devices. The PX needs no maintenance, is on the order of 96% efficient and pays for itself in electricity savings in about six years. Says G.G. Pique, the company's chief executive, only partly kidding: "We're getting close to a perpetual motion machine."

Hauge's first stop on his quest to conquer the desalination market was the Kuwait Institute for Scientific Research, which entered into a joint venture with Hauge in 1988 that provided him a staff, housing and a salary for three years to develop his product. Bad timing. Saddam Hussein invaded, and Hauge had trouble leaving the country. He thought he could escape with his pregnant wife through Baghdad to Jordan, but they were stranded in Iraq for three months.

He eventually made it to Virginia and established Energy Recovery in 1992. By then he had spent $500,000 raised from friends, Norwegian industrial foundations, his wife and credit cards. In the U.S. he funded his research with joint ventures with the German submarine maker Thyssen Nordseewerke and Virginia shipbuilder Newport News. A cash crunch in the mid-1990s forced Hauge to bring in new investors, like current ERI board Chairman Hans Peter Michelet and shipping magnate Morits Skaugen.

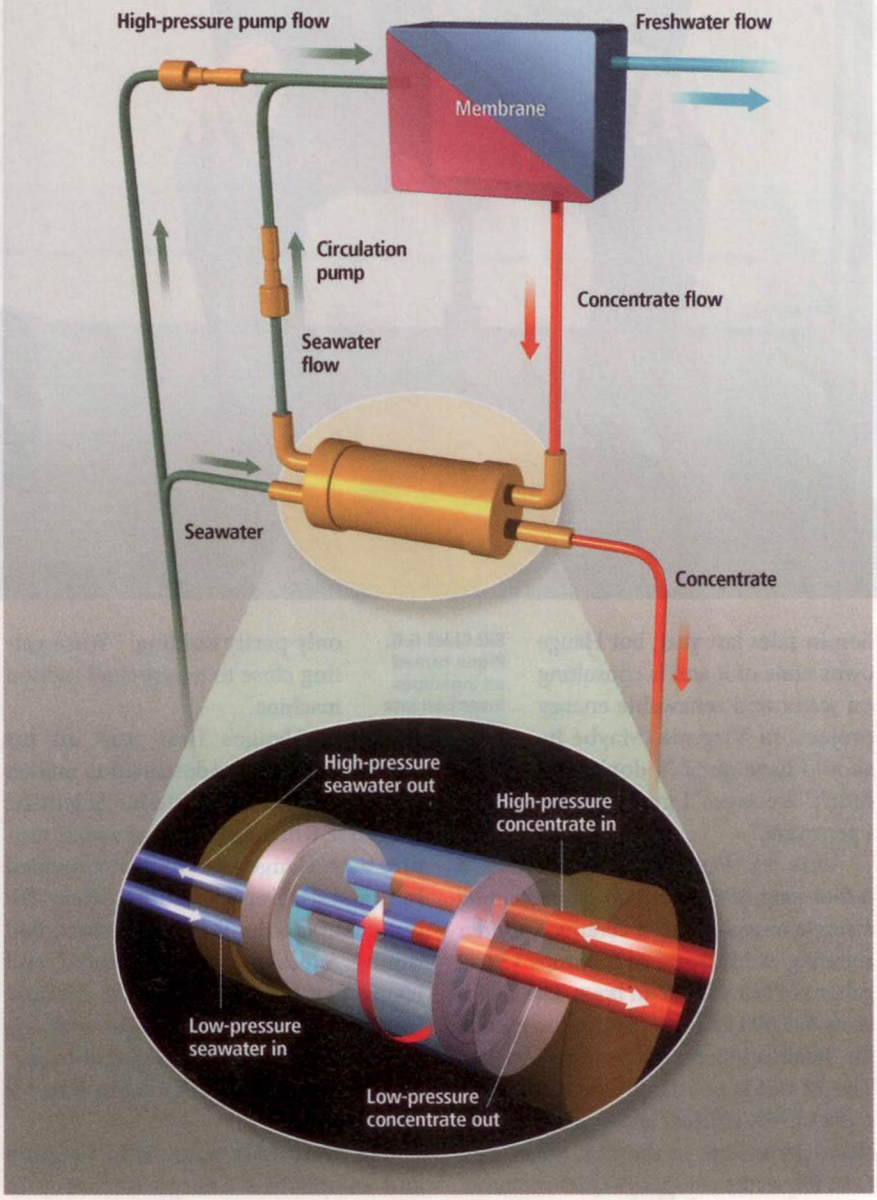
Competing pressure exchangers work by capturing energy in the exit water via a turbine (analogous to a waterwheel), then transferring that shaft power to a pump (waterwheel in reverse) for the entering seawater. Hauge's clever inven-

tion cuts the mechanical complexity in half. High-pressure exiting water enters columns in a rotor arranged like the bullet chambers in a six-shooter. This speeding water smashes into low-pressure water that has entered the same tubes at the other end of the rotor. Because water can't compress, the high-pressure water transfers nearly all of its momentum to the low-pressure water, pressurizing it, before turning back on itself and draining. The water enters and exits at slight angles, enough to spin the six-shooter chamber quickly, allowing the process to repeat 1,000 times per second. Surprisingly, very little mixing occurs *(see diagram)*, although a little bit wouldn't spoil the desalination. The freshwater output from the membranes is not part of the pressure exchange.

The mechanical ingenuity was only half the battle. The challenge was to find a material tough enough to withstand 1,000 pounds per square inch of pressure and

MOMENTUM TRANSFER

Much of the seawater forced against a desalination membrane bounces off, exiting at high pressure. ERI's device transfers that energy to incoming seawater.



SLIM FILMS FOR FORBES

inert enough to withstand corrosive saltwater. Several metal alloys, the final one a cobalt-chromium alloy, corroded or fused.

Frustrated, Hauge turned to ceramics, an idea given to him years before by a Danish company that had looked at an early prototype. He bought coffee mugs from Kmart and shaped them into rotors with a grinder. He spent two months at Oak Ridge National Laboratory working with precision ceramic-grinding equipment. He combed scientific literature for materials. He settled on a crystalline form of aluminum oxide called corundum—or, when pretty and polished, sapphire. Second only to diamond in hardness, it is strong and corrosion-resistant and can be lubricated by water.

In 1997 he installed his first devices in a small, 20,000-gallon-per-day desalination plant in the Canary Islands. But by then his new investors owned more of the company than he did. After the first installation the investors pushed hard for Hauge to market and sell devices quickly. But he had discovered some flaws and didn't think the device was ready. Also, because desalination plants are so complex, it took forever to get builders to design plants that incorporated his novel device.

He thought he had an agreement with majority shareholders that would let him retain voting control over the company. The board thought otherwise and removed him in 2000. Lawsuits and a bitter split followed. Hauge was left with nothing.

The timing was cruel. The volume of desalination power coming online, which grew 6% a year from 1990 to 1999, has been climbing 15% a year since then, according to the industry journal *Global Water Intelligence*. After the directors' first replacement for Hauge didn't succeed, they tapped Pique to run the company in 2002. Pique had worked in desalination since the early 1980s and had been consulting with ERI since 2000.

Pique retrofitted two large desalination plants, in Cyprus and in southern Spain, to showcase the company's pressure exchangers. In 2005 he opened a technical center in Madrid, the epicenter of desalination, to become more visible to builders like Acciona and Befesa. Pique took ERI public in May 2008; the stock trades at 40 times trailing earnings.

A large desal plant (13 million gallons a day) uses 50 or so of ERI's pressure exchangers. There are about 100 of these megaplants worldwide now, and 160 more are being planned, including a $400 million plant in San Diego County that will begin construction this year. The business is driven by both water shortages and economics. Nikolay Voutchkov, of Water Globe Consulting, says that a decade ago desalinated water cost $6 to $7 per 1,000 gallons of freshwater produced. Now it runs between $2.50 and $3.20.

Luis Castilla, president of Acciona's water division, tried ERI pressure exchangers in Peru in 2002 and now designs all of his big plants around them. Castilla's one complaint: They produce a painfully loud buzz.

ERI hopes to find new uses for the device in other industries, like oil and gas. It is trying to wedge its way into brackish-water treatment. (Because the osmotic pressure of brackish water is lower, the operating pressure of the desalination is lower and there's less cause for recovering energy from the waste stream.) For now the company has only one competitor, the Swiss company Calder, which Flowserve of Dallas, Tex. bought in April. It produces a device similar to ERI's, but Calder's is made of steel and has higher maintenance costs. This has allowed ERI to enjoy a 64% gross margin. It has only $450,000 in debt and $80 million of cash on hand.

"We're getting close to a perpetual motion machine."

Leif Hauge thinks his old company might yet be vulnerable. He held on to a single patent and thinks he can use it to make a device better than his first. It can't get more efficient, but he says it could be 20% cheaper to build and much quieter. It may take a while, and it may never work. Not that long odds would stop him. F