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$15,000 "Eat it!" Lemelson-MIT Student Prize Graduate Winner
Variable volute pump for energy savings in fluid systems

The Challenge: Centrifugal pumps, which are not often 'seen' by consumers, are key to moving water in ways that impact every aspect of our lives — from municipal water supplies to waste water treatment to crop irrigation. Centrifugal pumps move water within pipe systems and maintain system pressurization. Globally, pumps consume hundreds of billions of kilowatt hours of energy every year. Across the U.S., pumps use 6% of annual electricity production, approximately the output of 56 Hoover Dams.[1] In developing countries, it may be as high as 20% of electricity consumption.

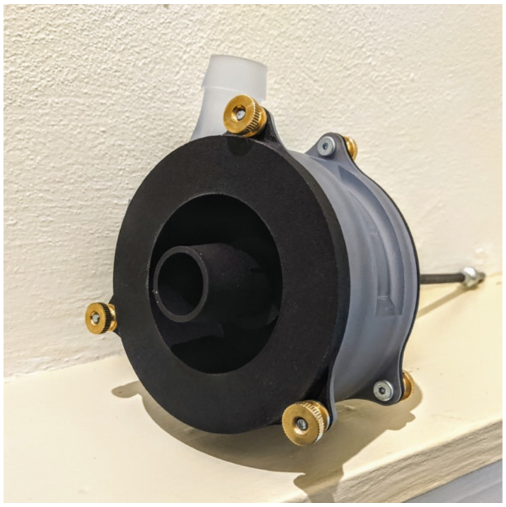
Centrifugal pumps rotate an impeller which sucks water in and accelerates it radially outwards using centrifugal force. The water is flung out of the impeller into a spiral chamber, the volute, where it collects before moving into the piping system. The volute converts the fluid energy from a high velocity flow into a slower, but higher pressure flow. Centrifugal pumps are designed to be most efficient over a target range of flow, and become much less energy efficient at higher or lower flow rates. Traditionally, the volute was a fixed volume, but water flow rates in most applications are variable. Because the volute cannot expand or contract to meet the changing system flow rate, more pumps are needed to accommodate high demand, but are underutilized during times of lower demand. This is a waste of energy and money, with negative environmental and economic consequences.

Industry needs pumps that can adapt to fluctuating flow needs to maximize efficiency and reduce environmental and financial costs. Unfortunately, volute size has never been adaptable, presenting a unique challenge to even expert engineers.

The Solution: Hilary's primary invention is a new type of centrifugal pump which adapts the volume of the volute, expanding and contracting to match the varying flow rate for better lifetime energy efficiency and environmental benefits.

[1] Johnson, H, Simon, K, Slocum, A. *Data analytics and pump control in a wastewater treatment plant*. Applied Energy, 2021. *In preparation*.

The variable volute pump works by physically adjusting the spiral volute passage, which collects high velocity flow from the impeller and converts the kinetic energy into pressure energy. The adaptive volute expands or contracts to match the operating conditions, proving more efficient by operating fewer gallons per minute than traditional pumps. The variable volute pump is able to maximize efficiency during operation by matching the volume of the pump to the varying volume of flow needed by the application. This matching reduces fluid swirl and hydraulic energy losses. Variable volute pumps can also be used for renewable energy efforts, such as pumped hydro energy storage used as batteries for storing energy from wind and solar renewables.



Prototype of the adaptive pump.
Photo Credit: Hilary Johnson

The Department of Energy estimates energy savings of 10-20% if pumps could adjust to demand as the variable volute pump does. Data show that Hilary's pump can operate efficiently across a broader flow range than the baseline, which shows potential to reduce energy, environmental impact, and lifecycle costs. The new mechanism is manufacturable, robust, and reliable.

Commercialization: Hilary has received sponsored research support through the Abdul Latif Jameel Water and Food Systems Lab (J-WAFS) at MIT and has collaborated with Xylem Inc., a global water technology company with $5 billion in annual revenue. J-WAFS and Xylem have both been strategic partners in Hilary's efforts. Executives at Xylem see her new variable volute pump as the first in a new category of adaptive pumps, and the company is poised to license and commercialize the technology. They are evaluating the mechanism's potential for initial commercialization in several clean water applications.

To see other inventions made by Hilary, visit her profile page on the Lemelson-MIT website, here: https://lemelson.mit.edu/award-winners/hilary-johnson.