THE HUNTSVILLE

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The Clean Energy Issue

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Fuel for the future

Flibe Energy revives safe, clean liquid fluoride thorium technology for the 21st century

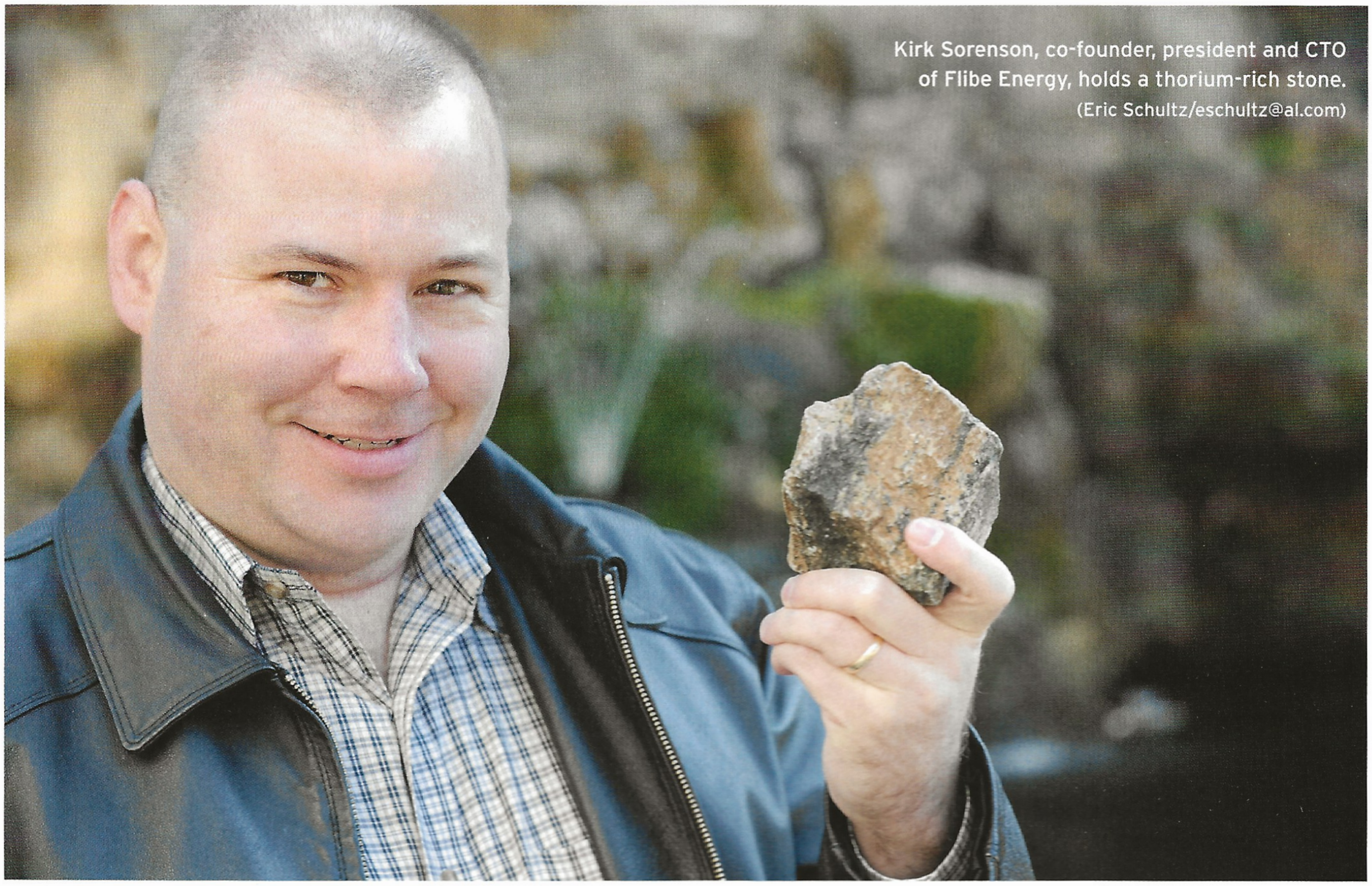
Fifty years ago, nuclear technology seemed poised on the precipice of an energy development breakthrough, with the potential to make nuclear power both safer and more efficient. In the 1960s, a team at Oak Ridge National Laboratories theorized that using gaseous salts in the form of liquid fluoride thorium – rather than uranium-based solid fuels – in a nuclear reactor could solve just about all nuclear problems.

Prompted by this theory, Oak Ridge built and tested a Liquid Fluoride Thorium Reactor (LFTR). Preliminary data showed that liquid thorium technology could provide a lifetime supply of energy with only ash for waste — so why abandon such an innovative, problem-solving technology?

That question set Kirk Sorenson, a former NASA aerospace engineer and the co-founder, president and CTO of Huntsville's Flibe Energy, on a quest for its answer back in 2000.

"I was an advanced propulsion specialist at NASA working on a nuclear rocket that could blast off from the ground into space, rather than being launched into space and turned on," Sorenson says. "In a meeting to accelerate my knowledge about nuclear rockets, I found this book entitled Fluid Fuel Reactors in Bruce Patton's office."

Patton worked at both Oak Ridge and Marshall Space Flight Center (MSFC). Learning of Sorenson's interest, he shared a story about a long-ago Oak Ridge project where researchers



Kirk Sorenson, co-founder, president and CTO of Flibe Energy, holds a thorium-rich stone. (Eric Schultz/eschultz@al.com)

> *We see this like the Saturn I – a first in a family of ongoing reactors.*

tested nuclear reactors using liquid fuels instead of solids.

After reading the 1,000-page tome, Sorenson spent $10,000 to have all project-related documents digitized so he could scrutinize the methods. Through distance learning, he earned another master's degree from the University of Tennessee in nuclear engineering, and prepared himself for the possibility his new passion was really just a dumb idea. "I'm intrigued by 1958 technology," he says. "It was like science fiction. There had to be something wrong with it!"

However, none of the experts he consulted thought it was dumb; in fact, they agreed lots of great ideas came out of the LFTR project and its hiatus appeared to be political rather than a failure of science.

"Funding was diverted from Oak Ridge at a critical stage of its development," explains Kirk Dorius, Sorenson's business partner in Flibe Energy, and VP and chief legal counsel. "That money went to the next shiny new project to come along – the fast-spectrum plutonium breeding reactor, and wasn't helped by the overriding attitude of the 1960s that there is 'plenty of gas' and 'everyone hates nuclear.'"

"At that time, no one was looking for an energy source that would save the world," Sorenson adds. "All mechanical engineers are interested in energy since it gets you where you are going and back, but only since 2000 has sustainable energy been a crisis."

Sorenson lists several essential benefits of LTFR over solid fuel nuclear power. First, a small handful of thorium can supply the lifetime energy needs of a single individual. Secondly, it operates at low pressure, is chemically and operationally stable; and produces safe, sustainable, carbon-free electricity. Abundant and inexpensive, thorium packs greater efficiency than costly solid-fueled reactors using enriched uranium; and it can fully consume long-lived plutonium and uranium fissile materials from spent solid nuclear fuel stockpiles.

The physics and operational fundamentals, both proven at Oak Ridge, show LFTR provides both base power and peak power per demand for electricity from the grid. Proliferation resistant and mass-produced in a factory, it is deliverable and reclaimed from utility sites as modular units. Most importantly, as a liquid salt-based fuel, thorium cannot fail or meltdown.

A crash course in nuclear

In its uranium oxide rock form, uranium is a non-radioactive ceramic.

"Enriching uranium," – the process that changes uranium in stages from its ceramic form into a gas, and then back into its ceramic 'solid fuel' form for use in a nuclear reactor – is grossly inefficient and costly because only a small fraction (about one part out of six) is actually enriched in the process.

In a nuclear reactor, enriched uranium fuel pellets are stacked inside metal rods with the ends welded shut.

"Inside the reactor is a vicious place where the very structure of matter gets warped because it splits the uranium into other things and those other things are radioactive," Sorenson explains. "During the fission process, only 2 to 3 percent of the uranium is spent, but over time, the pellets swell and elongate inside the metal cladding. These intensely radioactive rods must be replaced before the cladding cracks."

Efficiency, efficiency, efficiency

"Efficiency is catnip to an engineer," says Dorius. "And it's important because it translates into costs." One 12-foot fuel rod filled with uranium pellets uses up only 2 percent of the enriched uranium. That efficiency rate could make any self-respecting engineer cringe. Furthermore, spent nuclear fuel rods cannot be cooled enough to recycle.

"When we show engineers that liquid thorium is 100 to 200 times more efficient, we believe it will seduce them on a grassroots level."

Thorium in its natural rock form is also a ceramic, but the liquid thorium concept requires it to be a salt. When combined with fluorine ions, and melted about 600ºC, thorium takes on the texture of water, making it a liquid fuel.

"This is cool because salts are impervious to radiation damage; they are chemically indestructible, and self-regulating," Sorenson says.

While 1/3 of uranium rods are taken out of the reactor every 18 months and replaced with new rods, the remaining 2/3 are shuffled to different positions. All rods are removed after two to three cycles. Ninety-seven percent of the unusable uranium still exists, but because they are now radioactive, they are placed in spent fuel pools to cool down where, over eight to 10 years, radioactivity falls off. They are then placed in dry concrete casks, where thousands of them sit in the parking lots of nuclear power plants around the world.

"It is cheaper to load new fuel pellets than to recycle used fuel rods," Dorius explains. "You can see why retiring the fuel form before it is consumed is so inefficient, and why thorium, which burns almost 100 percent of the fuel and is not damaged by radiation, is so enticing."

Negative perceptions

The public generally holds antipathy toward the idea of nuclear power, believing it dangerous to the world's health and existence. Untimely accidents like Three-Mile Island seem to affirm the potential danger and conjure visions of mushroom clouds and disfigured citizenry poisoned by oozing radiation. Even though a nuclear power plant can't "go off" like an atomic bomb, its operation carries legitimate concerns due to nasty byproducts.

The basics of nuclear technology haven't changed in more than three decades. CFD Research founder and President Dr. Ashok Singhal is an

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Kirk Dorius, vice president and chief legal counsel of Flibe Energy. (Eric Schultz/eschultz@al.com)

Flibe Energy is in the design stage of building a pilot LFTR plant to test in a laboratory environment.

official partner of Flibe Energy on its modular LFTR systems. In 1978, Singhal was instrumental in developing technology for the Electric Power Research Institute (EPRI) project for Nuclear Steam Generators. That technology is still in use today by utility companies and energy vendors worldwide. Despite early progress, CFDRC left the nuclear industry in 2004.

"We found it to be a dying industry," says Singhal. "We now have a broader footprint in all forms of new energy fields without bias, including our own technologies in bio batteries, as well as geothermal, wind, solar and liquid fluoride thorium."

Singhal believes the world needs to exploit all types of power sources. "We face two distinct challenges: how to reduce the consumption, particularly the use of electricity and peak loads on current power plants and distribution grids; and how to increase the production and storage of energy from new sustainable resources and methods."

CFDRC's focus is the latter. Currently, Flibe Energy is in the design stage of building a pilot LFTR plant to test in a laboratory environment.

"We see this like the Saturn I – a first in a family of ongoing reactors," says Sorenson. "After 50 years, a lot has changed, but we are not starting from scratch. The Oak Ridge boys didn't know how particular materials would behave in this or that scenario. We've learned a lot since then. We are taking the best ideas from the Oak Ridge reactor to build a 21st Century model."

"Oak Ridge was a very successful first-of-a-kind demonstrator that showed the feasibility of some of the key fundamental physics and operation, but it was not an integrative commercial demonstration. We are taking designs they created but didn't get the funding to build; things they demonstrated and identified as needing development, finish the development, and integrate it into a commercially useful system."

Both Sorenson and Dorius point to private funding as the difference. Where Oak Ridge was completely government-funded, Sorenson says to make thorium technology work this time around, they have to have private money.

"Huntsville is already a nuclear community with the Browns Ferry Nuclear Plant. Redstone Arsenal is

This small ball represents the amount of thorium needed to power an entire community. (Eric Schultz/eschult@al.com) highly sensitized to energy alternatives since the 2011 tornados took out traditional power facilities," Dorius says. "Huntsville Mayor Tommy Battle's Energy Huntsville Initiative actively seeks to leverage Huntsville's existing professional capabilities into an effort to develop sustainable energy projects and industries.

"Huntsville is a can-do, moon-shot community. From an investor's prospective, we have a highly educated engineering talent pool, wide-ranging manufacturing capabilities and other technical competencies we need, like development in alloys, graphite, chemical processing and testing. We have companies who can help us design and build it, and partnerships with companies like CFDRC who are champions in physics-based modeling and simulation."

"Our partnership with Flibe is based on how we can accelerate their development of plan configurations and site demonstrations by exploiting the growing power of advanced computer simulations," Dr. Singhal explains. "Computer simulations let you screen through many alternatives of the design. If you just build and test, you will barely be able to afford one or two models, with lots of approvals, money, and safety precautions — unnecessary with our expertise in computer simulation. Flibe can do hundreds of variations of the same design utilizing a rapid screening method, rejecting less promising ideas."

"We are forming a consortium of industry stakeholders like utilities, heavy industry customers and supply chain providers who have a longterm, vested interest in the success of the technology as opposed to having a five-year exit strategy," says Dorius. "This way, we can provide Huntsville with long-term economic growth and energy-related technical jobs for a long time."

By Kimberly Ballard