Energy Demand, Climate Issues, and Safe Nuclear Power

A review of the lecture by Dr. Alexander Cannara, St. Albert the Great Hospitality Center, October 15, 2013.

Dr. Alexander Cannara is an electrical engineer, physicist, and green activist in Menlo Park, CA. He received a BSEE degree from Lehigh University, an MSEE in Plasma Physics, and a PhD in Mathematical Methods in Educational Research from Stanford University.

It is universally agreed that the world needs energy sources that are environmentally friendly. It is generally agreed that the world needs to develop a new supply of energy to satisfy the huge needs of the twenty-first century. Dr. Cannara's talk focused on methods of nuclear energy that have great promise and have been getting a great deal of attention lately.

Nuclear energy has a bad name in this country for several reasons:

- High perceived cost
- Lack of a solution for the waste problem
- Poor perception of safety (despite very good record)
- Proliferation of nuclear weapons

What we need is a next-generation energy source with the following features:

- Relatively low cost
- Inherently safe
- Resistant to nuclear weapon proliferation
- Does not have a long term waste problem
- Has the capability for rapid large scale development
- Does not release CO2 into the atmosphere.

Dr. Cannara mentioned several types of next-generation nuclear energy methods that are under research at present. He concentrated on one in particular: the liquid fluoride thorium reactor (LFTR).

Here is a summary of these technical terms, taken from http://thoriumremix.com/2011/, to which Dr. Cannara referred:

The predominant technology used to generate civilian nuclear power today, yesterday, and ever since we've had "nuclear power" is the Light Water Reactor (LWR). . . . Few today remember the alternate approach that was once actively investigated, the Thorium Molten Salt Reactor. Today the Thorium Molten Salt Reactor is frequently referred to as Liquid Fluoride Thorium Reactor (LFTR).

What is thorium and what makes it special?

Thorium is a naturally-occurring metal that holds large amounts of releasable nuclear energy via conversion to Uranium233 inside a reactor. This nuclear energy can be released in a special nuclear reactor designed to use Thorium. Thorium is special because it is far more common and cheaper than Uranium and, in a reactor, produces an isotope of Uranium that releases fission energy more completely, thus producing less waste material.

What is a liquid-fluoride (molten-salt) reactor?

A liquid-fluoride nuclear reactor is different from conventional nuclear reactors that use water and solid fuel elements. In particular, there is no water to explode to steam or release explosive hydrogen. A liquid-fluoride reactor uses a solution of several fluoride salts, typically Lithium fluoride, Beryllium fluoride, and Uranium tetrafluoride, as its basic nuclear fuel. Fluoride salts have a number of advantages over solid fuels. They are impervious to radiation damage, they can be chemically processed in the form that they are in, and they have a high capacity to hold thermal energy (heat) and transfer it to a generator or processing plant. Additional nuclear fuel can be added or withdrawn from the salt solution during normal operation.

Are the salts safe?

Very safe. Unlike other coolants considered for high-performance reactors (like liquid sodium) the salts will not react dangerously with air or water. This is because they are already in their most stable chemical form. Their properties do not change even under intense radiation, unlike all solid forms of nuclear fuel, and they’re not held under pressure.

What is nuclear waste and how does a liquid-fluoride reactor address this issue?

> So-called "nuclear waste" or spent-nuclear fuel is produced in conventional (solid-core) nuclear reactors because the fragments of fissioned atoms remain inside the solid fuel, reducing its usefulness. So solid-fuel reactors are unable to extract all of the nuclear energy from their fuel before they have to replace it. LFTR addresses this issue by using a form of nuclear fuel (liquid-fluoride salts of Thorium) that allows continuous, complete extraction of nuclear energy from the fuel.

Dr. Cannara peppered his talk with several props, one of which was a lump of Thorium, which he passed around, thereby demonstrating that the material was safe to handle. The lump was very hard, and had a metallic feel. Beach sand in India and Brazil are rich in Thorium and people even believe the mildly-radioactive sands provide health benefits.

He spent much of the time describing the advantages of the LFTR:

• **Relatively low cost**

Thorium is far more common and cheaper than Uranium. Construction cost per watt is estimated to be under $3, which is far less than current LWRs, and less than coal, or any combustion fuel, especially if carbon costs are applied. LFTRs have no need for expensive safety control or containment systems or emergency-cooling systems. No re-fuelling shutdowns are required because fuel can be added during operations, and there is no excess fuel in the core. We have enough Thorium in the United States to safely produce nuclear energy for thousands of years. Even Mars and the Moon have plenty of Thorium.

• **Inherently safe**

All Thorium is consumed in the reactor. There is no ”spent fuel” to worry about, whereas about 95 percent of Uranium in a conventional nuclear reactor goes unused, unless recycled as the French do. A LFTR running for 30 years, powering a city, would leave about 100 kg of radioactive materials that need storage underground for only hundreds, not thousands, of years. Salts are radiation stable, and gravity removes melt from the core. So there is no “runaway” or “meltdown.” Because the salt is not pressurized, there’s no potential for explosion.

• **No long term waste problem**

Typical wastes from a moderate size LFTR, over 30 years, is under 200 pounds (less than 1/2 cubic yard). Wastes are reduced on site to whatever low level is desired, and such materials need storage underground for only hundreds, not thousands, of years. Furthermore, independent of Thorium, MSRs (molten-salt reactors) have the capability to consume existing nuclear-reactor wastes. MSRs can consume most of our current nuclear-waste stockpiles. This eliminates the need for massive storage facilities for nuclear waste, such as Yucca Mountain in Nevada.

"A Thorium-fueled nuclear reactor generates hundreds of thousands of times the power of an oil, gas or coal power plant per pound of fuel, but produces essentially no waste. And a Thorium (LFTR) power plant would produce much less than 1 percent of the waste that a conventional Uranium plant of equal power produces, and, of course, would produce no carbon dioxide."[1]

• Capability for rapid large scale development

The LFTR is scalable from 1 Megawatt to multiple Gigawatts. and can be sited anywhere on earth or in space. The initial working MSR was designed for the Air Force's Atomic Plane; so it had to be small and reliable, with assembly-line production capability.

• No release of pollutants into the atmosphere.

There is no release of CO2 into the atmosphere in the operation of a nuclear reactor. Thus, human-caused climate change can be eliminated. About 25 percent of all past CO2 emissions are contributing to the problem of ocean acidification, thereby preventing plankton growth, affecting the entire sea food chain; and sea life provides twenty percent of human food protein. Even ceasing all CO2 production today will not prevent remaining airborne CO2 from dissolving in seas and threatening marine life. Thus new, clean energy is also required for processing materials that can be delivered to oceans to protect their chemistry and life. MSRs and LFTRs provide excellent high-temperature power to perform the necessary chemistry, as well as to make truly carbon-neutral fuels needed for aircraft, etc.

Dr. Cannara explained why this technology has not been exploited. The technology was thoroughly investigated[2] at the Oak Ridge National

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[1] http://www.thoriumenergyalliance.com
[2] http://en.wikipedia.org/wiki/Liquid_fluoride_thorium_reactor

Laboratory Molten-Salt Reactor Experiment in the 1960s. "Studies and experiments were conducted from the 1950's until the 70's. Over 17,000 hours of operation proved the true value of the MSR. "[3]It has recently been the subject of a renewed interest worldwide. Japan, India, China, the UK, and private US, Czech and Australian companies have expressed intent to develop and commercialize the technology. China in particular has announced a large research program, and has visited Oak Ridge to obtain research results from the 1960s and 1970s. For a summary of activity, see an article in the New York Times[4] on March 11, 2013.

So what happened?

The problem was that the MSR had to compete with already-developed naval LWRs, which became industrialized, and Thorium had to compete with natural Uranium as the fuel source to be developed. In the beginning of U.S. nuclear research, the objective was to develop a bomb, and that agenda had top priority. The Uranium reactor produces Plutonium usable for bombs. The LFTR resists diversion of its fuel to nuclear weapons in several ways.[5] LFTRs produce very little Plutonium, around 15 kg per Gigawatt-year of electricity (this is the output of a single large reactor over a year). This Plutonium is also mostly Pu-238, which makes it unsuitable for fission bomb building, but valuable for NASA's spacecraft power sources.. Secondly, a LFTR doesn't make much spare fuel. It could produce at most a few percent more fuel than it fissions each year, and a typical civilian LFTR would be designed to break even -- make less than 1 percent more fuel per year.

Finding a cheap technology for commercial uses of atomic power was not important at the time. Nor was perfect safety an issue. ORNL's Thorium MSBR (LFTR) research was de-funded in 1973, during the Cold War, when Plutonium production remained important. LWR technology had already gained acceptance, and no other technology has challenged it until recent years. At present, the U.S. Government is doing next to nothing.[6]

Dr. Cannara gave an extensive bibliography. There are two recent books on the subject which are both excellent: *Thorium: Energy Cheaper Than Coal*, by

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[3] http://www.thoriumenergyalliance.com
[4] http://www.nytimes.com/2013/03/12/science/in-search-of-energy-miracles.html?pagewanted=all&_r=2&
[5] http://en.wikipedia.org/wiki/Liquid_fluoride_thorium_reactor
[6] http://www.thoriumenergyalliance.com

Robert Hargraves, and *SuperFuel*: *Thorium, the Green Energy Source for the Future*, by Richard Martin.

The lecture was a part of the series called "Spirituality Tuesday" at St. Thomas Aquinas Parish in Palo Alto, CA. It was organized by the Parish Green Committee. The audience was a group of parishioners. For most of them, the technical aspects of the talk were beyond their experience, but they nevertheless appreciated the importance of the subject matter and understood the profound implications of the theme of the talk. Dr. Cannara is extremely knowledgeable in the field of nuclear physics, and he did not go easy on the audience in terms of scientific sophistication. Still, his friendly manner and breezy style were greatly appreciated. He is very approachable, and his objective is to help the general population understand the importance of nuclear energy and its possibilities, and to inform citizens so that they might push government agencies to invest in this technology.

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