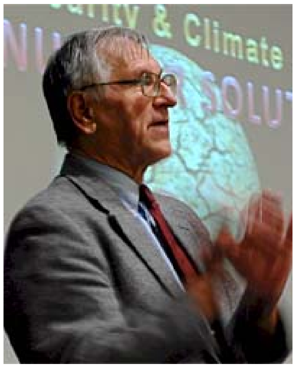
Nuclear Fission - Steady electricity without carbon, but is it worth the radioactivity?



Dr. R. J. (Jerry) Peterson gave this presentation at the December 10 meeting of the Colorado Café Scientifique at the Blake Street Tavern. Dr. Peterson is a long-time nuclear physicist researcher and is currently Professor Emeritus of Physics at CU Boulder, where he has also taught classes in International Affairs, Environmental Studies, Journalism; and in the Renewable and Sustainable Energy Institute. He has served the public as an NSF Program Director and as a Jefferson Science Fellow at the US Department of State.

Nuclear fission power plants provide about 20% of US electricity, humming away as base-line power for many years without generating CO2. There are 98 reactors in the USA, 448 worldwide, and more than 50 under construction. Are there better ways, technically, financially and politically to safely to provide this vital energy? Dr. Peterson reviewed the process by which fission generates heat, some history of experiments, how this energy is generated now, and a survey of some different ideas, including thorium and molten salt systems. The ideas are not new, as most of these methods have been studied in the past, with mixed results. Nuclear fission offers much promise for energy, but comes with two daunting problems: the connection to nuclear weapons and the radioactivity involved.

In the industrial revolution millions of years of solar energy converted to coal and oil and gas were harnessed as heat and fuel. Nuclear fission is another way of generating heat and electricity. Nuclear fission works when elements having at least twice the mass of iron break down and release energy. The uranium 235 isotope has an odd number of neutrons (143) and can easily gain another neutron and then release an average 2.4 neutrons. A nuclear reactor is stabilized so that it only releases 1 neutron, because additional neutron release would create a bomb. Only 0.7% of naturally occurring uranium is uranium-235; therefore it is necessary to either use a large amount of natural uranium or enrich it. (To illustrate how attitudes have changed, Dr. Peterson told how as a young boy under the “Atoms for Peace Program” in the Eisenhower administration he was able to order radioactive isotopes in the mail for one dollar per micro curie.) The 2.4 neutrons that result from the fission of uranium-235 have too much energy for a chain reaction; therefore they are slowed down by the interaction with protons (of similar mass) in water. High pressure, high temperature steam is generally used for this purpose. Natural uranium in a reactor is mostly uranium-238 and it captures a neutron to become uanium-239. This decays quickly to plutonium-239, which like uranium has an odd number of neutrons and can replace uranium-235 in a reactor. At the end of the life of a reactor about half of the fissions are from plutonium-239.

Thorium is the second heaviest element that can be mined and there exists 2 to 3 times more thorium than uranium. Thorium does not fission easily as it does not have an odd number of neutrons; therefore there must be considerable impact to create fission. Thorium in a uranium reactor will capture a neutron and transition to thorium-233, which decays to uranium-233. This element has an odd number of neutrons and behaves like uranium-235. India is the only nation that has taken the thorium path, as the country has little uranium but an abundance of thorium. Uranium-233 can produce a bomb and this has been accomplished by the USA.

The cost of uranium is a small part of the expense of operating a nuclear reactor (about 10%), unlike the cost of feedstock at a coal or natural gas plant. With a nuclear reactor the company is hoping to "pay back the mortgage from the construction costs" before anything changes (i.e. they lose their license.) About half the cost of a nuclear plant in the USA is due to paperwork, permits, and lawyers.

Reactors are more efficient at higher temperatures, which is where liquid salt reactors become important. Salts such as uranium fluoride are used. Liquid salt reactors are fast reactors, which mean that the neutrons are not moderated in water but are cooled with low pressure liquid metal rather than water. Plutonium, of which there is a surplus in the USA and Russia due to the Cold War can also be used (burnt) in a fast fission reactor. A fast fission reactor is more efficient at fission than making plutonium.

The Nuclear Regulatory Commission (NRC) has a fairly recent origin. Before its establishment the industry was run by the Atomic Energy Commission (AEC), which was charged with both encouraging nuclear power and regulating it. These responsibilities were separated after the Three Mile Island incident in 1979. The NRC redesigns proposed nuclear plants using their own analytical methods after obtaining the design proposal from the reactor manufacturer. This tends to stabilize nuclear reactor design and makes approval for less common designs difficult to achieve. For example, the drawbacks to a liquid salt or thorium reactor are largely regulatory because it is difficult to obtain design authorization. The NRC issues licenses for a 40 year operation and they can be renewed for 20 years at a time. The life of a coal or gas fired plant is only about 40 years.

An audience member asked about breeder reactors and why France has not destroyed the world with them. Dr. Peterson explained that breeder reactors were breeding plutonium. Uranium and plutonium are different chemical elements and thus the spent fuel rods can be dissolved and separated into distinct components. France and Japan built expensive facilities to do this and use the plutonium for fuel. This was previously done in the USA, but President Carter cancelled this program.

Another question concerned the computer virus that was used to infect another country's enrichment facilities. About 3-4 % uranium-235 is required to run a reactor, but the separation of the isotopes cannot be accomplished by chemical differentiation. Instead the uranium is converted to a gas, uranium hexafluoride, which is fed into centrifuge where the heavier isotopes fly to the outside and are siphoned off. This is repeated until the required concentration is reached. The centrifuges are about 6 ft long and are spun as rapidly as possible. The Stuxnet computer virus caused the centrifuges to spin in the wrong orientation and be destroyed. This act delayed Iran's nuclear weapons program.

A questioner asked about uranium versus thorium reactors and half lives. About 20% of the electricity generated in the USA comes from nuclear energy and about half this energy was previously aimed at us. That is, half of the power is produced from denatured highly enriched uranium purchased from Russia. Reactors change their fuel every 12 to 18 months for efficiency reasons. This spent fuel is initially stored in water and after a few years it is encased in concrete where it is stockpiled in the backyards of every nuclear power plant. Yucca Mountain Depository in Nevada was built to store spent fuel, but legal problems have stopped it being used. Nuclear reactors produce a variety of isotopes with a range of half lives. Dr. Peterson suggested separating the transuranics (isotopes with long half lives) from the fission products (isotopes with shorter half lives) and burying the fission products. The transuranics could be used for fuel; however this might cause potential bomb material to be too readily available.

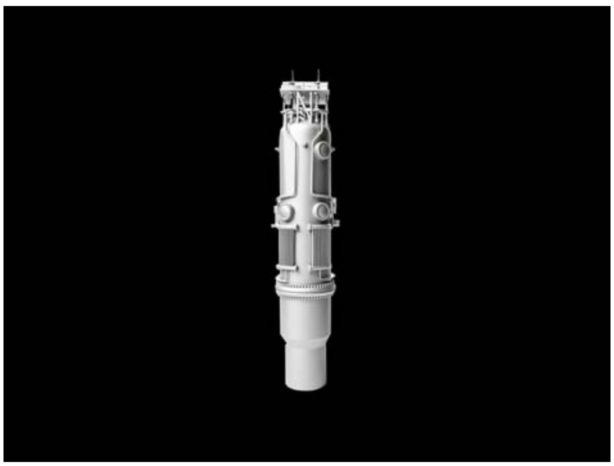
What do the French do about their spent fuel? France has a very strong national government and therefore edicts and standardization are easier to implement. They have a program for separating plutonium from spent fuel and built the Phoenix Reactors, which were powered by this plutonium. These reactors did not prove commercial.

Deep space probes are powered by both plutonium and solar panels. The probes are run by plutonium-238, which emits alpha particles. A golf ball-sized piece of this material will burn white hot. The plutonium is usually coated with nickel to reduce the radiation emission. Sometimes uranium-235 captures a neutron and does not fission, which provides a pathway to making plutonium-238. Because of the decline of the nuclear industry in the USA, plutonium-238 has to be purchased from Russia, which has raised the price.

Obstacles to nuclear power in the USA are regulations and perception. Because of regulations, molten salt reactors cannot be built as simply as they were in 1964. The consequences of an accident in a coal- powered plant are serious, but not catastrophic. Coal smoke contains many contaminants, but it is diluted and the population has learned to live with it. People suffer from a fear of ionizing radiation (radio phobia) and are thus concerned about nuclear accidents. Dr. Peterson showed the radiation emitted from a Coleman mantel which is impregnated with thorium oxide. Also, because of its altitude, the background radiation in Colorado is twice the national average. However the cancer mortality for the state is the lowest in the nation since it has a young, clean-living, well educated population with good health insurance.

How does nuclear power compete with wind and solar technology? The nuclear facilities are mostly competing against gas-fired plants that are cheaper. Nuclear reactors run best when they run consistently and they don’t compete well on the grid with intermittent power sources, particularly wind, but also solar. Grid operators prefer that less than 20% of their power comes from wind due to its fluctuations. Germany has invested heavily in solar and wind power. With stormy days in the North Sea, the producers often must pay their customers to take their wind energy.

How many reactors are in the State of Colorado? There are no power reactors, but the USGS operates a research reactor at the Colorado School of Mines in Golden.



NuScale Reactor (65’ tall and 9’ wide)

What is the status of small scale fission? To date the economies of scale have prevailed in making large reactors (a gigawatt or more), although at a point, these efficiencies disappear. A recent idea is to use small modular reactors which, like trailer homes, are manufactured and shipped to site. When their lifespan is over, they are returned to the factory. Twelve modular reactors would be required to run a big city. A problem with the small concept is regulation, as the NRC design review process is rooted in large scale reactors.

Why did the EPA decide to tear down part of Uravan and ship it to Utah? Uravan was a milling town, started in the early 20th century with radium production. In the Second World War the tailings were reworked for vanadium. Finally, during the Cold War, uranium was extracted. These three episodes of mining history produced much contamination.

Sources say we will have controlled fusion plants by 2040. What is your opinion? The ITER (International Thermonuclear Experimental Reactor) facility in France is a scam. The proposed fuel is not hydrogen, nor deuterium, the stable isotope of hydrogen. ITER designs utilize tritium, which has both 10 times the yield and 10 times the probability of functioning. However, the use of tritium produces fast neutrons that will induce radioactivity in all surroundings. There is no present way to couple the fast neutrons to generate power for the grid.