NUCLEAR POWER

Rubbia Floats a Plan for Accelerator Power Plants

When you are already a Nobel laureate and have spent the past 5 years in charge of the world's leading high-energy physics laboratory, it must be hard to dream up fresh challenges. But Italian Nobelist Carlo Rubbia, who steps down as head of the CERN particle physics center in Geneva at the end of the year, has lined up a project that should prove sufficiently demanding: attacking the world's energy problems by applying particle accelerator technology to the science of nuclear power generation.

Rubbia's plan, outlined in a seminar given at CERN this week, is to develop a design for a nuclear reactor fueled by thorium rather than the conventional uranium. Thorium does not readily undergo nuclear fission, but if bombarded with neutrons, it can be transformed or "bred" into uranium-233. Nuclei of uranium-233 are fissile, so if they too are hit by neutrons, they will split in two releasing energy and more neutrons. These neutrons can both induce further thorium breeding, and promote yet more fission of the resulting uranium-233.


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There is life after CERN. Retiring director Carlo Rubbia.

The problem is that this chain of events produces too few neutrons for the thorium cycle to become self-sustaining in a conventional reactor. That is where particle accelerators come in: If a high-energy beam of protons is shot at a target of heavy nuclei, it knocks out neutrons. So an accelerator could be used to supply extra neutrons to drive a thorium cycle reactor which, in turn, should yield energy far in excess of that needed to power the proton beam. "Accelerators produce neutrons at a low energetic price," Rubbia explains.

Rubbia stresses that the idea should not be oversold. "It's very speculative," he says, noting that all that exists at this point is the theoretical framework. And while Rubbia is convinced that a thorium-fueled system will be economically viable, he will have to produce some convincing figures: Variations on Rubbia's theme have been explored by researchers working for Atomic Energy of Canada Ltd. (AECL) and by a team at the Los Alamos National Laboratory, but so far, the nuclear industry has shown little interest. Indeed, AECL abandoned its research on thorium fuel in the early 1980s because "the economics were never there," says Jim Ungrin, manager of AECL's accelerator physics branch.

Rubbia, however, is undaunted. He argues that the thorium fuel cycle offers some important selling points. While it still yields radioactive fission products and a range of uranium isotopes, the thorium cycle produces few highly toxic, long-lived radioactive nuclei, such as neptunium-237, which are common in waste from conventional reactors. And because the thorium cycle produces little plutonium, the risk of weapons proliferation should be minimized, Rubbia says. Finally, there is a safety advantage: Because fission reactions can be sustained only when the accelerator is working, a runaway nuclear accident is impossible.

Rubbia and a handful of CERN colleagues have already produced several preliminary designs for what Rubbia calls a thorium-fueled "energy amplifier." They propose two basic models. First, the thorium fuel itself could act as the target for the proton beam and the device would be cooled using water, which would also act as a "moderator"—slowing neutrons to maximize their interactions with thorium and uranium nuclei. In the second design, the beam could be trained on a separate target, such as a molten mixture of lead and bismuth. Graphite would be used as the moderator rather than water, allowing the system to be run at higher temperatures so that the excess heat generated by fission can be converted to electricity much more efficiently.

Any real engineering work must first await the verification of the basic idea of energy amplification pumped by a proton beam, however. Rubbia's team hopes that will come soon: It is now trying to get time on CERN's smallest accelerator, the PS-Booster, to test key aspects of the scheme. The first step is a proposed $700,000 experiment to fire protons at a uranium-233 target to see if this induces sufficient fission to give the 30-fold or more energy gain that Rubbia predicts. That would still leave untested the thorium breeding part of the cycle, but "if it works for uranium, it will work for thorium," asserts Rubbia.

Rubbia notes that physicists have long realized that bombarding fissile materials with neutrons produced by an accelerator might achieve a net energy gain. "I've not invented this idea," he says. Rubbia's scheme also borrows from ideas developed by a group led by nuclear physicist Charles Bowman of the Los Alamos National Laboratory. Over the past 3 years, Bowman's team has devised a system using a proton beam from a powerful linear accelerator that would produce neutrons to drive a thorium breeding and fission cycle, while at the same time breaking up, or "incinerating," dangerous nuclear material—such as weapons-grade plutonium, and the highly toxic long-lived nuclei produced by conventional nuclear generating stations. "The business of dealing with the waste stream is the key to the future of nuclear power," argues Bowman.

By simultaneously destroying waste and generating power, Bowman's machine would be "cleaner" than the designs put forward by Rubbia, as the radioactive waste produced by the system itself could all be broken up into short-lived, safer products. Rubbia's system, while producing much less hazardous material than a standard reactor, would still generate some relatively long-lived waste. And that, Bowman believes, will favor his approach. Rubbia, however, counters that Bowman's design—which requires liquid fuel and continuous chemical processing to separate out fission products—poses some technical difficulties. "If you only want energy and don't care about burning waste," he argues, "you can go to a much simpler system."

Despite their differences, Rubbia and Bowman face the same difficult job in convincing a skeptical nuclear industry that the thorium cycle is worth pursuing. Thorium ore is abundant, but at the moment so is uranium. That's one reason why AECL abandoned its line of research. AECL scientists explored the idea of using particle accelerators to breed uranium-233 from thorium, so they could extract this uranium to use in standard reactors—essentially doing in two steps what Bowman and Rubbia want to do in a single system—but there was no economic incentive to breed thorium into uranium.

Given this climate, Bowman—who hopes to interest the U.S. Department of Energy in funding a $540 million, 6-year program to develop a demonstration model of his design—believes the sudden entry in the field of a well-known figure like Rubbia may have a positive effect: "His interest is, I think, going to be very helpful in getting the recognition that this approach deserves."

–Peter Aldhous