BOB HIRSH'S ATTACK OF THE TOKAMAK 12/18/2015

Since leaving the government magnetic confinement fusion program and the field in the mid-1970s, Bob Hirsch has contributed a series of diatribes against the most successful concept being developed worldwide in that program. His latest such contribution was presented to his former colleagues at the Fusion Power Associates meeting in December, 2015, which was essentially a rehash of an article published in *Issues in Science & Technology* earlier in the year. .

In his FPA talk and the article, Hirsch complains that the tokamak uses technologies that have been known to fail sometimes, decries that the ITER tokamak presently under construction is more expensive than a conventional light water nuclear reactor (LWR) that can be bought today, argues that the radioactive waste problem is worse for tokamaks than for fission reactors, points out that the confinement of tritium is a safety issue and concludes with a clarion call for setting a new path in fusion research (without any specifics about what path would avoid the problems he foresees for the tokamak, only suggesting fatuously that it lead to an economical reactor that can satisfy regulatory requirements). His arguments are disingenuous (at best), misleading in the extreme and should not go unchallenged.

Components do fail, particularly in the early stages of development of a technology, but there is a learning curve. Hirsch mentions e.g. superconducting magnets quenching in accelerators, causing long downtimes for repair and constituting a potential for explosions (he even shows a picture of a totally unrelated bomb explosion), and plasma disruptive shutdown in tokamaks. This argument, while based on identified problems that are being addressed, ignores the learning curve of technology improvement that has been followed by all technologies. Bridges have collapsed and airplanes have crashed, with much more disastrous consequences than a tokamak shutting down unexpectedly would have, but improvements in technology have now made these events acceptably unlikely. Why can the same technology learning curve (e.g. quench protection or high-temperature superconductors, disruption mitigation) not be developed for magnetic fusion technologies?

Hirsch's economic arguments based on comparison of the estimated cost of ITER and of a Westinghouse AP-600 LWR are disingenuous and completely ignore both the learning curve and the difference in purpose of ITER and of an AP-600. ITER is being built by an international collaboration entered into by the 7 Parties (USA, EU, Japan, Russia, China, S. Korea, India) for sharing the expense of gaining the industrial and scientific experience of building and operating an experimental fusion power reactor, most of the components of which are first-of-a-kind, therefore requiring the development of new manufacturing procedures and a large and continuing amount of R&D. Each of the Parties wants to share in this experience for as many of the technologies as possible. In order to initially achieve the ITER collaboration, an extremely awkward management arrangement was devised, including contribution in kind of the components and the requirement of unanimity among all Parties on all major decisions. By contrast, the AP-600 benefits from a half century learning curve in which hundreds of LWRs have been built and operated, many of them by the single industrial firm (Westinghouse) that offers the AP-600. A more meaningful comparison would be to cost an AP-600 to be built in the 1950s (escalated to today's dollars) by the same type of consortium as ITER, involving the same Parties with a similar purpose, and requiring the development in 1950 of what would be first-of-a-kind components of the present AP-600.

Bob's very questionable argument that a tokamak power reactor will have a larger mass of radioactive waste than a fission power reactor displays a lack of appreciation of the difference of radioactive waste from future fusion reactors (activated structural material that for the most part will decay to negligible radioactivity levels in 1-10 years) and fission reactors (highly radioactive fission products and transuranic elements, the latter of which will still be highly radioactive 100,000 years later, necessitating secured storage on that time scale)—mass is not the issue.

The containment of tritium in a hot metal environment is indeed an issue for fusion. However, it is an issue that has been faced and solved in the tritium production fission reactors that have operated for more than half a century to fuel thermonuclear weapons, so there is no reason to believe that it can not be solved in fusion reactors.

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