Letters

EDITOR:

I am writing regarding the article "High Temperature Superconductivity" by David L. Goodstein (Winter 1989, Vol. 52, No. 2). On page 12 of that article Prof. Goodstein discussed nuclear fusion and stated ". . . magnetic confinement is no longer the system of choice. As a matter of fact, I don't think there is a major research group in the world working on magnetic confinement. It's just not the way the problem is being approached these days."

From this statement it appears that Prof. Goodstein was unaware of the state of affairs in the fusion research field. On speaking to him I found that he really meant to say "magnetic mirror confinement" rather than "magnetic confinement." Magnetic *mirrors* are confinement devices that have indeed been shelved, but the term magnetic confinement includes tokamaks, stellarators, reverse field pinches, field reversed theta pinches, and several other concepts all of which are being pursued vigorously. It is important to correct the misleading impression left by Prof. Goodstein's statement, and so I would like to summarize here the true status of magnetic confinement research.

First of all, magnetic confinement *is* one of the two systems under consideration (the other is inertial confinement), and there are many major research groups around the world working on magnetic confinement. The U.S. spends about $350 million annually on magnetic confinement, and Japan, Euratom, and the Soviet Union are all spending similar sums. Superconductivity is of potential relevance to magnetic confinement and, in fact, both Japan and the Soviet Union have built tokamaks with superconducting coils.

Second, Prof. Goodstein wrote that "nuclear fusion, the promise of limitless energy from seawater or something, has been just around the corner since World War II and is still just around the corner," implying that there has been negligible progress in this field. Although there have indeed been instances of optimism, in general the scientists involved have realized that fusion research, being one of the most challenging technical problems addressed by man, would take both a long time and much effort before success would be achieved. There has actually been enormous progress. To appreciate this, let me briefly restate the requirements for generating useful energy from nuclear fusion (called "break-even"): One must (i) heat a deuterium-tritium plasma to temperatures over 100 million degrees Kelvin, while (ii) simultaneously confining the plasma so that the heat does not leak out. The critical parameter for requirement (ii) turns out to be the product of the plasma density times the energy confinement time, and a working fusion reactor would require this product to exceed 10^{14} particle seconds/cubic centimeter. In the 1950s the best plasma temperatures obtained were about 1 million degrees and the confinement parameter was about 10^{9}–10^{10}; in the 1960s these improved to 5 million degrees and 10^{10}–10^{11}; and in the 1970s 50 million degrees and 10^{12}. Now, in the 1980s the Princeton TFTR tokamak has achieved ion plasma temperatures of over 100 million degrees (for comparison, the temperature of the core of the sun is 15 million degrees) and confinement parameters a few times 10^{13}.

These parameters correspond to being within about a factor of four of break-even (these experiments have all been done in deuterium plasmas; tritium injection is being temporarily postponed because of the careful handling required, and because it is more important to put the limited resources available into further improving the plasma). Similar results have been obtained on the European JET tokamak. The world fusion community is now designing the next generation of machines, which will operate well into the break-even regime. The U.S. program is suffering somewhat because of funding limitations caused by the current deficit problem, and it seems possible that the lead established here might be taken over by the Japanese (who are going full speed ahead) or the Europeans (who have been quite good at coordinating their resources to build JET).

Paul M. Bellan
Associate Professor of Applied Physics

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EDITOR:

Paul Bellan is exactly right about my goof. I deserve a double reverse theta pinch for saying such a thing. Furthermore, Paul isn't the only plasma physicist to object to me about that one. There were times when my phone heated up to well over 10^{8} kelvins (Paul is wrong about calling 10^{8} kelvins "100 million *degrees* Kelvin").

On the other hand, nobody has reached me to object to any of the other outrageous assertions in the article. I take this to be a good sign.

David L. Goodstein
Vice Provost
Professor of Physics and Applied Physics

EDITOR:

Thomas Carroll's letter in the Winter 1989 issue brought back memories of the late 60s and early 70s on campus. Tom writes that he is proud to have been the cordial undergraduate who appeared on the cover of *Engineering & Science*, volume 35, number 5, March-April 1972. Caltech should also be proud—for staying calm during those turbulent years. The cover photo shows a student facing away from the camera, waving the peace sign to the two human figures on the space-bound Pioneer 10 plaque that someone had caricatured on a construction wall near Beckman Auditorium. Tom writes fondly of Floyd Clark and the photo session, but that's not the whole story.

You see, Sarah Ingersoll, my wife, had painted those figures several months earlier, and I'm proud to have been her accomplice. This confession still leaves