EIR Science & Technology

The plasma focus and building fusion reactors

In the second of a two-part series featuring the work of Dr. Winston Bostick, Charles B. Stevens examines the application of the plasma focus for fusion reactor materials development.

*Part I of our series discussed the fact that the plasma focus has been relegated to the scientific basement because it tends to produce apparently anomalous results that routinely baffle scientific opinion. Even so, it has continued to progress experimentally in small laboratories throughout the world, to the point where it has demonstrated the capacity for many near-term applications. Among the applications discussed last week (*EIR*, May 27, 1988) were the utilization of plasma focus to generate short-lived radioisotopes for medical and biological diagnostics, especially the two scanning techniques called positron emission tomography and computer axial tomography; the ability of the plasma focus to provide a test-bed for developing materials and engineering technology for thermonuclear reactors; also touched upon was the capability of the plasma focus for generating relativistic beams for ballistic missile defense purposes.*

It has long been recognized that realization of thermonuclear fusion power reactors based on the neutron generating deuterium-tritium fusion reactions will require development of entire new arrays of materials. These materials range from structural components, insulators, magnets through to heat transfer mediums, and energy conversion systems.

The deuterium-tritium fusion environment represents a major challenge from the materials standpoint. The fusion plasma will operate at temperatures of hundreds of millions of degrees. This plasma will irradiate reactor components with fluxes of high-energy neutrons—several million watts per square meter—which will deeply penetrate into reactor components and the "first wall" of the fusion reactor chamber, in particular. These fusion-generated neutrons actually contain 80% of the fusion energy generated, so that once the neutrons are deposited within the "first wall" of the reactor, the heat energy generated must be efficiently transferred out of the reactor to electric generators.

And while hot plasma and electromagnetic radiation will interact with the surfaces of various reactor components, and thus cause significant wear and tear, it is the effects of the deeply penetrating neutrons which determine the most difficult problems for designing efficient and economical fusion reactors. These deep penetrating neutrons generate a wide variety of effects which degrade reactor components. For example, the fast neutrons undergo many collisions with the atoms of the material making up the first wall. These collisions cause these atoms to be displaced from their normal positions in the crystalline lattice structure of the first wall material and eventually lead to the material losing its mechanical strength.

Neutrons also generate nuclear reactions within the first wall. These reactions can produce a number of deleterious effects. First of all, they generate radioactive materials that make the first wall too radioactive to handle and repair. This induced radioactivity can also be a serious safety problem. Some of the reaction products are in the form of gas, which causes the first wall materials to swell in volume and undergo various other forms of degradation.

These unique nuclear effects must be combined with more conventional materials problems, such as holding up to thermal and mechanical stresses which will take their toll, especially since most fusion reactors are based on cyclical designs which mean that these parameters will be changing over time.

While many of these effects can be theoretically extrapolated from existing experience gained with nuclear fission reactors, the only certain way to test the full and combined effects is to recreate the same environment that will be found in a fusion power reactor itself.

Recent advances in the experimental performance of the plasma focus indicate that this device could be capable of generating these required conditions at a cost ten times less than other alternatives.

The Stevens Institute submitted a design to the March, 1988 San Diego International Energy Agency Workshop on Requirements for an International Fusion Materials Irradiation Facility for an advanced plasma focus Compact Accelerator Plasma Target (CAPT) system that would meet the requirements for fusion reactor materials development and testing.

The experimental results from plasma focus experiments over the past several decades demonstrate that this compact device has some of the best scalings for producing fusion so that it would be possible to reach levels required for reactor materials R&D with a relatively small system. Recent advances have significantly improved these already good scaling laws.

For example, Stevens Institute researchers have developed a technique involving the introduction of an electric field distortion during the breakdown and initiation phase of the plasma focus. This field distortion is caused by the introduction of a knife edge near the insulator end of the focus. The field distortion leads to the generation of a much more tightly packed moving plasma current sheath which, in turn, leads to a tenfold increase in fusion reactions produced when the plasma pinch forms. The field distortion has also eliminated plasma focus misfirings and creates conditions in which the lifetime of the insulator at the breech of the coaxial electrodes is increased by a factor of 100 to 1,000.

Repetitive modes of operation have been also demonstrated ranging from up to 1 million shots per second down to 2-10 large-scale shots per second which combine trains of many plasma sheaths to form one final pinch plasma.

Professor Vittorio Nardi of Stevens presented to the Workshop the latest experimental results, which demonstrate that a compact 10-million-watt neutron output plasma focus could be constructed at costs many times lower than other proposed devices.

Dr. Nardi reviewed a two-stage proposed program. A $20 million dollar demonstration facility could be constructed and tested within 3 years. It would consist of a 1 megawatt, .5 million joule plasma focus. The final facility would cost about $100 million and be completed within 4 years; and would be a 5-megajoule plasma focus with a 10-megawatt neutron output for testing fusion reactor materials.

Interview: Winston Bostick

Near-term uses of the plasma focus

Dr. Winston Bostick of the Stevens Institute of Technology in New Jersey is the world's leading pioneer in plasma focus research.

EIR: Could you outline what some of the near-term applications of the Plasma Focus are?

Bostick: One of the most promising is the creation by fusion with elements of Z greater than 1--that is, a higher atomic number than 1--specifically, carbon and nitrogen, the creation of radioactive isotopes, short-lived, which can be used in tumor tomography. It's called PET: positron electron tomography. These isotopes up to now are created by cyclotrons, but now the plasma focus can do it more economically, and it is basically much more efficient, because the plasma focus uses a very hot plasma target. The target and the accelerator are all really one very small volume, where there are very high magnetic fields and very high electrical fields generated. And the deuterons are accelerated and contained in these high magnetic fields, and the plasma focus does all of this. . . .

EIR: How quickly could this application of the plasma focus for positron electron tomography be developed?

Bostick: It could be developed very quickly. You see, the technology is already developed for the use of these isotopes, as manufactured by the cyclotron. The plasma focus, which would cost perhaps only one-tenth of what the cyclotron costs, would be much easier to operate and could be installed in many, many hospitals, which would make it possible for every medium-sized hospital to have a plasma focus machine to generate these isotopes; and tomography for locating cancer, locating tumors, especially tumors in the brain, would be available for every one of these hospitals. The technology for imaging has already been developed, but the role of the plasma focus would be to make these isotopes available in a much more universal and economical way.

EIR: How soon could that be done, if you had the funds to go ahead?

Bostick: The machines already are in a laboratory state; we should package them and make them so that a trained hospital technician could learn how to use the machine; and this, and the packaging of the machine for commercial sale, could