The Ultimate Automobile

By Louis P. Solomon with Dick Van Orden

In a previous column, we discussed various approaches to solving future energy problems of the United States. Now we are ready to take up the most promising solution for consideration: Nuclear power reactors for generation of electricity.

There are two types of nuclear power generation:

> Nuclear Fission—The splitting of a heavy atom into smaller atoms, with the release of heat energy and two or three neutrons.
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> Nuclear Fusion—The combining of two light atoms, releasing large amounts of heat energy and no radiation products.

We have previously discussed the Fission option, which is well-known and is in use at the present time. Fusion, still under development after many years, is less well known and continues to be extremely difficult to initiate and run under controlled conditions.

Nuclear physics, is a complex subject, and difficult to explain in simple terms. However, we will try our best, even though we may oversimplify at times.

As we previously discussed, nuclear fission is used in a nuclear power plant to produce heat; the heat is delivered to water to produce steam, which is then used to turn a turbine generator to produce electricity, just as steam from a coal-fired, or oil-fired, or natural gas-fired plant produces steam to turn a turbine generator. A fusion reactor would perform in the same manner, but the heat is produced differently—by a fusion reaction rather than a fission reaction—as might be presumed from its title.

Nuclear fusion is inherently different from nuclear fission. In the fission reactor we split the uranium atoms, and regulated the rate of splitting by using control rods. These rods slow down the fission process by absorbing excess neutrons thus keeping them from causing other atoms to split and produce heat in excess of the heat needed. A nuclear fission reaction is self sustaining, and controllable. However, the physics of nuclear fusion is different.

The process of generating a <u>sustained</u> fusion reaction that can be used for power generation has not yet been achieved. It requires large amounts of energy to initiate a nuclear fusion because the repulsive forces (protons) of the atoms must be overcome. Once the repulsion is overcome, the energy of the combining atoms far exceeds the energy required to force them together, hence it is a beneficial process to generate heat energy. Once the fusion is initiated, there must be enough heat energy to continue to force nuclei together in order to sustain the reaction. Our sun and our stars are examples of a nuclear fusion reaction.

Since hydrogen has only one proton, it has the smallest repulsion force that must be overcome, hence the fuel used in a typical fusion reactor is hydrogen. Two hydrogen ions "fuse" into a helium atom with the generation of high speed neutrons. This fusion process produces heat, far more than was required to start the fusion, and enough to sustain the fusion reaction, if properly controlled.

One of the first steps in building such a reactor is to create a “plasma” (a fourth form of matter, after gas, liquid, and solid). When a gas is heated to very high temperatures (several million degrees Kelvin) all the atoms lose all their electrons. This collection of nuclei and free electrons exist in a state that is known as a plasma.

Some technical issues are how to hold the plasma. This is achieved by using very strong and focused magnetic fields. The magnetic fields are difficult to build, and they must be very strong. They have to hold the hot, dense plasma long enough for the nuclei to fuse and the reaction to be sustained.

The coupling of the plasma and the magnetic fields is a very complex system. This world-wide research has been continuing unabated for over 40 years. The United States has been focusing on fusion reactor development, in partnership with the Russians, the Europeans, and the Japanese. There has been amazing success, with results approximately one million times better than only 20 years ago. Plasma fusion regularly is achieved, but not quite long enough to have a sustained reaction. That is clearly coming.

What is so wonderful about fusion reactors is that the fuel used is water. Any kind of water, including sea water, grey water (sewer output), contaminated water from industrial uses, etc, will serve as the fuel. The water can be used to generate hydrogen, which then becomes fuel for a nuclear fusion reactor. The results of the reaction are heat, steam, helium, and hot water. There are no radioactive products.

Electrical power is clean and safe. The methods of generating electrical power are still based upon the burning of petrochemicals and coal, producing the attendant carbon dioxide and other waste products. Nuclear fusion power is essentially inexhaustible and environmentally very friendly. But, we aren’t quite there yet.