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UP/DOWN FUSION AND FISSION*

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EXTENDED ABSTRACT

Fusion reactors, unlike fission reactors, are a marvelous potential for man in his quest for ever greater amounts of power. We think we know how fusion reactions work, but we cannot start building such plants. The fusioning of atoms of low mass into atoms of heavier mass, with a release of excess heat, can take place only when the temperature of the atoms is many millions of degrees of temperature. Such conditions may exist within stars, and the commonest mechanism is the "burning off" of hydrogen accompanied by a slow build-up of helium. The inner workings of a fusion reactor must consist of a highly chaotic swarm of charged particles. Containment will be accomplished, if at all, by a magnetic bottle type, force field, which is created inside a vacuum chamber. Excess heat will reach the vacuum chamber walls as radiant heat and a bombardment of neutral particles not stopped by the magnetic forces.

Since vacuum chamber walls will be metal, they will act as a window to fast neutrons which will be thermalized and captured by lighter materials external to the chamber walls, which will in turn create showers of hard gammas. The reactor rooms of fusion power plants will be radioactively "hot" during operation, and must be shielded, using thick concrete walls much as in fission plants. Here, any similarity ceases. Irradiated material within fusion reactor rooms will become radioactive in time, but these materials will be non-toxic, of lighter mass, far fewer in number and of shorter half-life. In the event of accident there will be no release of radioactive material into the ambient environment, as can happen in a fission reactor plant. Man-made, steady state fusion "fires" should be very easy to turn off in view of the egregious technical difficulties involved with starting and maintaining them. Unlike most power plant systems, it is not possible to start on a small scale. If a system is devised that is practical, it will be big and very expensive. The tremendous costs can be justified if the station capacities in KW are very large. Unlimited power would be available through fusion reactor plants and fuel is totally plentiful.

We should intensify our R&D efforts to solve the extremely vexing technical problems. If we succeed, we will have no energy shortage and can envision practical space travel, not only to other solar planets, but to other stars. That we may not succeed should not deter us; at least we would have tried. Inability to predict when we will succeed, if ever, makes it vital that we also develop alternate energy sources that will allow us to exist here on earth as we want to, for as long as we can. I recommend a THUMBS UP VOTE for fusion power plant development.

Fission reactors may be likened to the other side of the nuclear coin. The technology exists. There are many types, ranging from small research

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reactors, plutonium production reactors, fission reactor power plants, to A-Bombs. Fission reactors can have fast neutron fluxes moderated or thermalized using heavy water, beryllium, carbon, light water, or not at all. Reactor thermal heat can be removed using recirculated coolants such as liquid metal, helium gas, pressurized light water, boiling light water and pressurized heavy water if reactors are large. Very small reactors can be cooled by immersion in swimming pools, mechanical ventilation or by detonation. Fuel can be plutonium, enriched uranium or natural uranium in the form U_3O_8 in zirconium cans.

America and other nations have spent enormous sums on various atomic programs relating to the use of fissionable materials for peaceful purposes as well as war. We have produced reliable A-bombs and can use them to trigger H-bombs. The detonation of an A-bomb lasts a few thousandths of a second after a critical mass is initiated. The yield of fissions relative to maximum possible fissions is low. The weight involved is a few tens of Kg. Nonetheless, after several years, growing traces of radioactive fall-out were found in forage. Today, prudent nuclear nations detonate test devices underground. Mobile fission reactor power plants in the order of 10,000 KW were developed to drive nuclear missile-laden submarines. Once a power reactor is turned on, it is, in about 10 minutes, as radioactive internally as it will every be, and final cooling of spent fuel will take in the order of a million years. Nuclear submarine plants contain a few hundred kilograms located behind packed lead shielding canned in a wetted steel hull located below the waterline. A core meltdown in port would not threaten landlubbers. Submarines lost at sea end up under great depths of water and radioactive contamination is remote. During the same period we cancelled a program to power planes using reactors as unnecessary, very expensive and downright dangerous.

Numerous fission reactor power plants have been built and put into operation in the absence of a decision as to what to do with nuclear wastes. Right after World War II, many of us wanted to see peaceful uses of atomic power come to the fore. Almost unwittingly we "crossed the Rubicon" as practical systems were developed. Of most interest are the two light water moderated "boiling water" and "pressurized water" systems which require 3% enriched uranium fuel, and the CANDU reactor which is moderated and cooled using heavy water. Although first reactor plants were small, today we have plants of three units of 700 MW capacity or two units of 1100 MW capacity. Single unit plant sites are normally sized for added units and the possibility of enclaves of units has been publicized. Large fission reactors involve a few hundred thousand kilograms of fission products (and unspent fuel) at a large power plant site. Spent fuel elements must be removed and replaced with fresh fuel elements if the plants are to continue to produce power. Typically, light water moderated plants must be shut down for a year while this change is effected. In sharp contrast, the CANDU reactors can have fuel elements of natural uranium oxide replaced while in operation. Instead of building extensive separations and enrichment facilities, or "buying American", they opted for an extensive plant on Hudson Bay to separate heavy water from seawater.

No safe plans have been developed to dispose of nuclear ashes. This is because there is no safe way. The media have referred to many plans. A recent suggestion was to rocket wastes to "another galaxy." The media have also reported escape of small quantities of plutonium from containment at Hanford, Oak Ridge and in Canada in recent years. We cannot bury the stuff because a future Mount St. Helens could spread it all over. We cannot blast it into outer space because rockets can blow up on the pad, or malfunction with uncontrolled reentry and burn up high in the stratosphere with a resulting fine distribution. We cannot park the stuff in Antarctica which has not always been arctic and has coal seams and residual insect life. In far less than a million years the fission product containers could be deep in salt water under corrosive attack. Pelletizing fission products in glass blocks sounds great until one sees sizable pieces of glass being pounded into sand on any beach. The safest place to leave spent fuel elements is in the safety containers wherein they became radioactive.

A recent report [1], written by two Englishmen, on what happened at Three Mile Island, was very well done by authors of impeccable background and contains 11 diagrams and graphs. A number of points of interest were described. The core of the stricken reactor was bared to steam as opposed to water three times in the early going. One instance was very brief but, during the other two, meltdown of fuel elements took place. Maximum fuel element temperature reached or exceeded the melting point of zirconium fuel cans, which is 2,128°K or 3,830°R. The off-site irradiation was extremely low. A series of radioactivity readings, taken at 20 minute intervals, starting four hours after the accident, were 200R/hr/ 600R/hr, 1,000R/hr and 6,000R/hr. Readings were taken behind 4" of lead some 20m above the reactor. At 600R/hr, 90% of people exposed will die. Finally, borated water has been used to cool the burned-out core which now has a friction of 200-400 times normal value, and will require equivalent cooling for hundreds of thousands of years. Boron ten soaks up thermalized neutrons and prevents resumption of core meltdown (Boron ten is 19% of all boron atoms).

Let us consider current economics of fission power plants. A recent report [2] on three Commonwealth Edison fission power plants, of 2,156 MW, 2,240 MW and 2,240 MW capacity, stated delays of eight months, 12 months and 24 months, for completion in 1982, 1984 and 1986, at new estimated construction costs of 2.0, 2.7 and 3.1 billion USD (or 928, 1,205 and 1,384 $/KW). A very late report on five Washington Public Power Supply Systems (WPPSS) states construction costs rising from 4 billion USD in the early 1970s to 11.8 billion in 1979 to 15.9 billion in 1980. The five WPPSS plants are four to five years behind schedule [3]. To this must be added the cost of fuel elements starting with $50/# for U_3O_8 [4], cost of fuel enrichment and cladding, the cost of pumping borated water for an eon if something goes wrong, up to 500 million USD if a core meltdown ruptures containment, and the future cost of "safe disposal" of nuclear ashes for a million years per spent reactor core if nothing goes wrong. These plants are also labor intensive due to need for operational health physics and frequent shutdowns.

These plants cannot be justified because they are only 25% efficient, are very expensive, nuclear fuel is rarer than coal, oil and gas, and they operate about 67% of the time as opposed to 88% on-line record of fossil-fueled plants. Breeder reactors are said to create more fuel than consumed to the extent that fuels will last longer by a factor of 60. Breeder reactors make more sense, but not enough sense. While nuclear fuel could be regenerated again and again, cost per plant is much greater, on-line time will be no better and chances of accidental escape or theft of nuclear wastes are greatly increased. Many of the above points were contained in an earlier publication /5/. It is concluded that fission reactor power plants of large size are obsolete and should be SHUT DOWN SYSTEMATICALLY, as other, safer, and less expensive methods of power generation come into use. The great hope of nuclear power generation for the benefit of man lies with fusion reactor plants.

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