Fusion for Earth and Space

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Abstract. The compact reactor concept presented at the STAIF-2007 has the potential to provide clean, safe and unlimited supply of energy for Earth and Space applications. The concept is a potential fusion reactor wherein deuterium nuclei are preferentially fused into helium nuclei. Because the deuterium nuclei are preferentially fused into helium nuclei at temperatures and energies lower than specified by the standard model there is no harmful radiation as a byproduct of this fusion process. Therefore, a reactor using this reaction does not need any shielding to contain such radiation. The energy released from each reaction and the absence of shielding makes the deuterium-plus-deuterium-to-helium (DDH) reactor very compact when compared to other reactors, both fission and fusion types. Moreover, the potential energy output per reactor weight and the absence of harmful radiation makes the DDH reactor an ideal candidate for individual home and space power. The concept also would make it possible for each plant or remote location to have it's own power source, on site, without the need for a connection to the power grid. This would minimize, or eliminate, power blackouts. The concept could replace large fission reactors and fossil fuel power plants plus provide energy for ships, locomotives, trucks and autos. It would make an ideal source of energy for space power applications and for space propulsion.

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BACKGROUND

Today the rate of energy usage has increased until there is a tremendous amount of discussions, writing, and worry over the world's energy future. Along with this concern is the attendant concern over the impact of the use of various types of energy upon the world's ecological system. The current design of fission power plants has input chains that are accompanied by radioactive materials that require careful handling and special treatment. The production of nuclear energy in fission reactors releases nuclear radiation that requires a great deal of shielding for safe operation. The waste products that result from the fission reactor are also radioactive and need careful handling and storage indefinitely.

A new theory of physics (Williams, 1983, 2001, 2007) offers an alternate energy supply that does not have the problems of current energy production. It is based upon fusion energy so there would be no use of hydrocarbon fuels. The fuel supply chain for the reactors has NO radioactive materials. The fusion reaction is two deuterium nuclei fusing to form a helium nucleus. This reaction goes forward at temperatures low enough to avoid other reactions that produce radiation. The waste product of this energy generation is helium so that no harmful radioactive waste material is produced. This provides clean energy from abundant fuel material with no harmful waste products.

Non-Singular Potential

The new reason this fusion reactor design may be made now and could not be made with the standard model of nuclear physics is the non-singular electrostatic potential that may be derived from Weyl's Gauge Principle when Weyl's Quantum Principle is required (Williams, 2001, 2007). It has been shown (Williams, 2001, 2007) that when these two principles are applied Maxwell's equations produce a non-singular electrostatic potential:

$$f_r = \frac{k}{r} e^{-\frac{\lambda_N}{r}} \tag{1}$$

where the subscript in the exponent indicates that the exponent depends upon the particle's gauge potential quantum numbers, as $\lambda_N = K\lambda_0$, and may be, therefore, different for different particles. Indeed the K is dependent upon the gauge potential quantum numbers, N_j. If Weyl's Quantum Principle is not required the potential of Equation (1) reduces to the classical electrostatic potential. The k appearing in the numerator also depends upon the particle as it is the usual electrostatic constant $(Z_1e_1Z_2e_2)/4\pi\varepsilon_o$.

At this point a simple question might be asked, "Why has such a non-singular potential not been noticed?" Predictions of such a potential have been seen for decades, but have been misinterpreted. For example, the first proton-proton scattering produced high energy results that deviated from scattering predicted by the singular, coulomb potential and it is now argued that this deviation is due to a strong nuclear force that does not appear in the Maxwell equations for electromagnetism. The non-singular potential predicts that a neutron is a proton trapped in a nuclear orbit around an electron (Williams, 1983). This proton orbit is the result of a positive energy well from which it is predicted to tunnel with a half life matching that experimentally measured (See Figure 1). All disintegrations of neutrons are accompanied by the emergence of a proton and an electron together with motion of the center of mass. This is exactly what is predicted by the non-singular potential. The standard model of the neutron does not speak of its composition as the Heisenberg uncertainty relations are used to argue that an electron cannot be confined to the interior of a neutron. It has been shown that the unit of action in quantum mechanics is a function of the gauge potential and within the neutron the gauge function reduces the units of action for both the proton and the electron to 0.66586ħ and $8.0517\text{x}10^{-4}$ħ respectively which match the spins of the neutron and its ejected components (Williams, 1983). The standard model argues that beta decade of a nucleon, when an electron is emitted, is the result of the weak nuclear force which also does not appear in Maxwell's electromagnetic equations. It has been shown that the forces currently argued as the result of weak nuclear forces are predictable as the force between un-like particles with non-singular electrostatic potentials (Williams, 1983, 2001).

The predictions of the non-singular potential are not limited to these two cases of misinterpretations (Williams, 1983, 1997, 2001, 2007), but these should suffice to show that the effects of such a non-singular gauge potential are seen throughout the universe. Yet these effects are not ascribed to a non-singular potential even though scientists have worked hard to rid physics of the singularities of the Coulomb potential through renormalization.

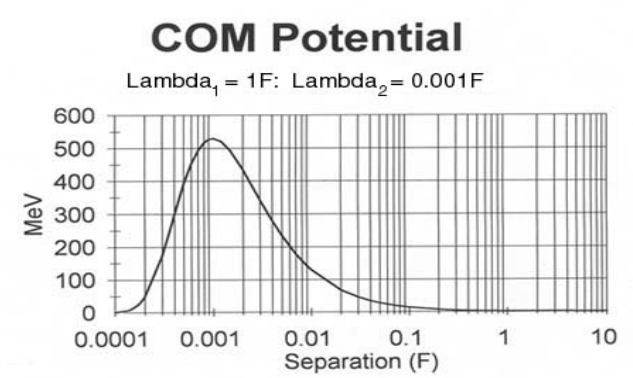

Figure 1. Positive potential well of the Center of Mass of a neutron.

FUSION REACTORS

It was shown that the non-singular potential of Equation (1) leads to a nuclear model wherein the deuterium nucleus consists of two protons in a nuclear orbit around a single electron. A helium nucleus is then four protons in orbit around two electrons. The fusion reaction of two deuterium nuclei fusing to form a helium nucleus may then be enabled by a magnetic field that aligns the orbital axis of the orbiting protons in neighboring deuterium nuclei which are then nudged together as in Figure 2.

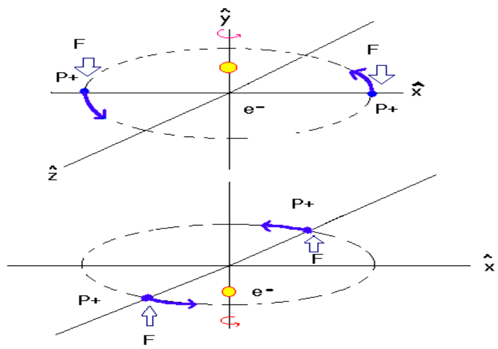

FIGURE 2. Two Deuterium Nuclei Being Nudged Together.

The helium nucleus that forms by the fusing of two deuterium nuclei is shown in Figure 3.

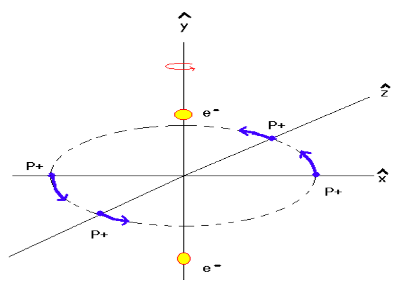

FIGURE 3. Helium Nucleus Formed From Two Deuterium Nuclei.

The fusion reactor needs to be designed so as to facilitate this reaction and to collect and carry away the energy released by the reaction. One means of facilitating the reaction is to hold two deuterium nuclei in near proximity of each other in such a way that a magnetic field may be applied so as to align the proton orbital axis of two nearest neighboring deuterium nuclei. This may be done by forming a crystalline Deuteride with a non-magnetic host material. A method of reaction control is obtained by using a crystalline structure to hold the deuterium nuclei. One is that there is at least one plane within the crystal that contains only deuterium nuclei. This means that a magnetic field may align the proton orbital spin axis parallel to this plane and be assured that a host material nucleus will not be between the deuterium nuclei. The maximum fusion rate should be obtained when the magnetic field is further aligned within the plane of deuterium nuclei so that the proton orbital spin axis are aligned on the line between two deuterium nuclei with minimum distance between them, i.e. nearest neighbors. The second control assistance offered by the crystal structure is that the magnetic field may be aligned so that proton orbital spin axis may be aligned so that a host nucleus may be placed between any two deuterium nuclei. This turns the reaction off by putting a host nucleus in the path of potentially reacting deuterium nuclei.

The rate of reaction may be calculated by quantum tunneling using the crystalline structure to obtain the initial separation of the deuterium nuclei and the vibration due to temperature to provide the velocity in the calculation. It must be understood that the fusion potential is not the simple non-singular potential. Rather the fusion potential is determined by integrating the forces between the six bodies that make up the two deuterium nuclei that are initially separated and the helium nucleus that is formed. The integral of these forces with respect to the separation of the two deuterium nuclei gives the fusion potential. It is true that like particles repulse each other, however, when the proton orbital spins are aligned all four protons are attracted to both electrons and at the same time the protons can move away from the other protons so as to balance the forces of attraction and repulsion.

Collecting the energy released due to the fusion reaction means that a gamma absorber needs to be placed around the fuel material as the energy should be carried away in the form of gamma rays. The number of gamma particles and their frequencies has not been estimated yet. In the standard model of nuclear physics the fusion reaction of two deuterium nuclei fusing into a helium nucleus is thought to be extremely rare and little experimental data exists to provide knowledge of the number and energy of the gamma that come from that reaction. Yet, as the binding energy of deuterium is of the order of 2.2 MeV and the binding energy of the helium nucleus is 28.3 MeV it might be expected that these values be the bounds on the energy of the emerging gamma.

Of the three methods of gamma absorption, photoelectric effect, Compton scattering and pair production, the last two would be expected to dominate the absorption at these higher energies. Compton Scattering may be relatively independent of the atomic number, but pair production is more effective as an absorption method in heavier nuclei. Other effects of gamma absorption in material, such as the Mossbauer Effect, involve, or at least consider, the recoil effect of absorption and the influence of this upon the temperature of the material. Of course, the rapid transfer of the energy from the gamma to heat is desired. Once the energy of the gamma is determined research may be conducted with the perhaps new objective to optimize the properties of materials that aid the transfer of the gamma energy into heat energy. It should be expected that such research would include using the nuclear model provided by the non-singular potential to seek nucleon energy levels that may aid the absorption of the specific gamma energies.

The method by which the energy is carried away may depend upon the reactor application and certainly will affect the size and weight of the resulting reactor design.

One of the first hydrides that may come to mind when thinking of designing fuel for these reactors might be LiH. This is known to general come in powdered form with few large chunks of approximately ¼ inch in maximum dimension. The question of how to obtain a sufficiently large solid of the fuel to allow the use of the magnetic control field should come up. The Los Alamos National Laboratory previously established a method of growling large crystals of LiD for material characterization studies (Pretzel, et al, 1960).

Large Scale Reactors

A large scale reactor such as one for use on a ship or at a major power plant (approximately 10 MW and higher) will likely work best by carrying the energy away through conversion of the heat generated in the gamma absorber by boiling water or by a pressurized water system. This means that a large scale reactor may be designed in such a way that the fusion reactor simply replaces the fission reactor in current power plant designs. Thus there is no major difference between a large scale fusion power plant and current fission power plants in how the heat is carried away. The real difference lies in the generation of the heat. This difference is a large difference.

The fuel material for the fusion reactor is a crystalline Deuteride that involves no radiation. The reaction, being the preferential fusion of two deuterium nuclei to form a helium nucleus, emits no radiation. The waste product, helium, is non-toxic and emits no radiation. Therefore, no special handling of either the fuel or the waste is necessary, though collecting the helium produced may have advantages. This offers a serious reduction of hazards in the use of a fusion large scale reactor. The reduction of special handling and required shielding offers great reductions cost and size of the large scale fusion reactors.

Intermediate Scale Reactors

An intermediate scale reactor (0.5 to 5 MW) may be made using this fusion reaction that could power trucks, trains and other mobile users of power. Locomotives have fairly large volumes available for developing the power they need. They also have a well-developed generator and motor final drive system. Typically locomotives need high power output levels without the demand for rapid power level changes that is placed on a truck engine. These factors argue that direct steam generation might offer the best method of carrying the energy away from the reactor for locomotive applications.

The typical manner in which trucks are used places many demands for rapid power level changes upon the engine. Rapid power level changes are not supported easily by steam systems. Over the road trucks might be able to use steam systems to carry the energy from the reactor, but delivery trucks would probably not be a candidate for steam.

Small Scale Reactors

A small scale reactor may be made using this fusion reaction that would be useful in remote locations and within the home. The difference between the large scale reactor and the small scale reactor is in the manner by which the energy is carried away from the reactor. For example, the fuel and the gamma absorber material may be encased within a shell of thermoelectric diodes so that the heat energy is converted into electrical energy and carried away electrically. The power output desired of the reactor would establish the thickness of necessary thermoelectric diodes needed.

How the electrical energy is handled once removed from the reactor also would depend upon the application. For example a small remote reactor may power a direct current load that requires no conditioning of the electric energy. On the other hand, if the reactor is to be used for an individual home where 25 to 50 kwh of energy is needed per day then the energy may be used in a couple of ways. The reactor may be used to maintain a bank of batteries in a fully charged condition. This would allow a small reactor of some 1 to 2 kw to be used as a constant battery charger while the batteries allow for large, short duration demands. Solid state inverters may be used to convert direct current energy into alternating current for those applications requiring alternating current.

A home reactor that is capable of responding to variable load demands needs to rely upon rapid power level control by the controlling magnetic field. This reactor application would require that the reactor be sized to meet the peak demand as there is no storage of energy to assist with short term high load demands. This type of application may require a reactor capable of producing 50 kw or more.

The use of fusion reactors to power personal automobiles also may involve small, constant output reactors to keep electric car batteries charged. Or, if the size of rapid response reactors of approximately 50 kw output is not prohibitively large, these reactors might be used in autos without the need of batteries.

Space Reactors

The use of reactors in space has special demands placed upon them. This is especially true when considering the waste heat produced by reactors used in space where the removal of waste heat is made more difficult by the absence of a gas or fluid to carry this waste heat away from the generating source. By using thermoelectric diodes that generate electric power due to a temperature difference across the diode means that waste heat is reduced to that left over by the lowest possible operating temperature of the thermoelectric diodes. Since the temperature of space is close to absolute zero anything operating at a higher temperature will radiate heat away into space. However, the transfer of his heat to space is retarded by the near absence of a conducting medium. Therefore, the lower the operating temperature can be made for the outer shell of thermoelectric diodes the less the temperature difference between the reactor energy extraction system and the surrounding space and the less heat wasted.

THE IMPACT OF FUSION REACTORS

The development and use of the above series of fusion reactors would significantly impact several sectors of our lives and the Earth’s ecology. This impact should be considered before and during any development of these reactors.

Reduction of Fossil Fuel Use

The potential development of all sizes of the above discussed fusion reactors would make a significant reduction in the demand and use of fossil fuels. For example as fusion takes over the responsibility of providing electric power the use of coal would drop considerably. The use of coal for home heating would also be unnecessary when home fusion reactors begin supplying energy for the individual home.

Fusion automobile power plants coupled with fusion power plants driving trucks, trains and ships would markedly reduce the use of gas and oil. Even the use of natural gas and oil for home heating would not be needed for the home with its own nuclear reactor.

The author has not spent much time thinking of how a fusion reactor might be used to power aircraft and, therefore, leave this topic to others who may have given it some thought.

The reduction and virtual elimination of the use of fossil fuels would have a tremendous impact upon the Earth's environment. The pollution currently produced would be almost totally eliminated. The production of green house gases almost stopped.

Economic Impact

The economic impact of the above series of fusion reactors would be even more striking than the impact upon the reduction of pollution. Perhaps the production, distribution and use of energy involve more political power, money and individual wealth than any other industry or chain of industries. This power and wealth alone may cause the potential of the above series of fusion reactors to become 'dead on arrival.'

Economic Impact on Energy Production

The global impact of the transfer of wealth due to oil production and sales is constantly in the news. Countries and individuals owe their wealth and well-being to the money that their oil production brings. Individual and country wealth have followed energy production since the beginning of the industrial revolution set in motion by the control of energy. Those countries and individuals whose wealth is based solely upon the production and sale of oil would see their source of wealth dissipate with the development of the fusion reactors. This short paper cannot, nor intends to try to, do justice to a discussion of the economic impact that the above fusion reactors would have on energy production.

Coal production by the five top coal producing countries exceeds some 5,000 Mt per year. This represents a significant portion of the world's energy production following behind that of the oil industry. This industry would also see a reduction in the demand for its product with the development of fusion reactors.

Economic Impact on Energy Distribution

Energy distribution is big business. Every home owner or business owner or operator has a utility bill that covers the energy used. Many, if not all, of these distribution companies also produce the electric and gas forms of energy that they distribute. Some may have nuclear and water-driven power plants to generate some of the electric energy they distribute while almost all have oil or coal fired power generation plants. Large scale fusion reactors would eliminate the need for these oil and coal fired power plants.

Industries that have large plants that use a lot of energy may install their own large scale reactor and not need to draw their power from a distribution grid. Indeed with homes installing individual reactors the large power distribution grids may become a relic of the past. While this might wreck havoc with the distribution companies' income, it would eliminate concern over a power grid failure from either a breakdown or terrorist act.

At first blush it may appear that the utility companies may lose their income should the fusion reactors replace the oil and coal powered plants. However, this may not be mandated by such development. The fusion reactors must be manufactured and maintained. This could be the role of the utility companies. They could manufacture or obtain the reactors and then deliver them to each home through sales or leases and provide for the minimal maintenance they require.

CONCLUSION

The non-singular potential leads to a very different model of nuclear physics and particles than the standard model. In particular, the deuterium nucleus consists of two protons in nuclear orbits around a single electron. This knowledge gives rise to the prediction that if two deuterium nuclei are in near proximity of each other and a magnetic field is used to align the spin axis of the proton orbits with the line between the two nuclei, then vibration due to thermal heating allows the calculation of fusion rates through quantum tunneling. This provides for the preferential fusing of two deuterium nuclei to form a helium nucleus. This preferential fusion reaction produces no radiation. The fuel chain has no radiation safety hazards. Also, the waste chain has no radiation hazards nor needs any special handling.

Large scale fusion reactors may be made using either pressurized water or direct steam means of carrying the heat away from the reactor. A power plant wherein the fission reactor is replaced with a fusion reactor will experience a significant reduction is size and weight. Part of the size reduction is due to the difference in the reactor size based upon the greater energy liberated by fusion as compared to fission reactions. Another reason for the reduction in size and weight is that there is no need for any radiation shielding since there is no radiation produced.

Small scale fusion reactors may be designed to use a direct conversion of heat energy into electrical energy by thermoelectric diodes. These small reactors may be used as battery chargers with almost constant output or as variable output reactors that may respond to variable load demands of a home, business or automobile.

Intermediate scale reactors may be designed use either direct conversion of heat energy into electrical energy or they may use steam as an intermediate between the heat of the reactor and the electrical load.

The development of a series of fusion reactors will have a significant impact upon several aspects of life on Earth. It will significantly reduce the world oil and coal production and alter much of the national transfer of wealth that has attended oil and coal production. The development of the series of fusion reactors will allow for the generation of electrical energy at the point where it is to be used thereby eliminating the need for the current large electric power grids. This will have an impact upon the utility companies that currently own and operate the power distribution grids and it will eliminate the hazards of large power outages due to mishap whether accidental or intended.

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