Fusion is the future

COLD/FUSION/PROJECT

A research project on thermonuclear fusion by Ronald Hohls

Introduction

In today's rapidly growing world, electrical power is continuously increasing in demand. The United Nations estimates that the world population will top 9 billion by 2075. We are clearly at an era of energy crisis and are in urgent need of a new energy source.

Even today, primative coal power remains our primary source of energy. Scientists have now come to the scary realisation of what global warming really entails, with the recent discovery of global dimming. This ultimately means that coal energy definately is not an answer, as it pollutes. Alternative possibilities include, renewable sources such as the sun in the form of solar and wind power; nuclear power in the form of fission; and others such as geothermal power,heat from the earth. Whilst solar and wind power are becoming more prominent in developed countries (they contribute as much energy as nuclear), they are costly to build and do not present a definite solution for the future, they simply cannot supply enough energy.

Many call for an increase in nuclear power. In nuclear fission lies clean energy that is renewable and will meet future power demands, but again there is a downside. As a by-product of fission, nuclear wastes are produced and these require careful storage as they remain radioactive for thousands of years. Hence fission is also not an appropriate solution.

I believe that our solution lies in nuclear fusion. Fusion is clean, has no radioactive by-products and produces five times the energy of fission. I believe that all efforts in energy research should be focused on designing a successful fusion reactor that will replace all other forms of energy. I believe fusion is the energy source of the future.

Whilst fusion is yet to be mastered and while many scientists have deemed this task as highly improbable, there are those who remain adamant that it is well in our grasp. They are of course referring to the theory of cold fusion. In my research of fusion energy, I have also come across this theory and it aroused great interest in me. Simply not trusting the conclusions of others, I set myself upon the task of replicating cold fusion.

The basics of nuclear physics

At the basis of everything is matter. EVERYTHING in the universe consists of matter and all matter consists of atoms. At the heart of all atoms is a positively charged nucleus, containing various protons (+ charged) and neutrons (neutrally charged). The element of any specific atom depends on the amount of protons, whilst the neutrons determine its isotope. For example, the element Hydrogen has only one proton and no neutrons; however its isotopes of Deuterium and Tritium each have one and two neutrons respectively. Different isotopes of an element share some characteristics and often have the same appearance. Elements on the other hand differ greatly from one another.

The nucleus is surrounded by a "cloud" of negatively charged electrons. The mass of an atom is concentrated in the nucleus. Thus the atomic mass of a nucleus is the sum of the protons (**Z**, atomic number) and the neutrons (**N**, neutron number). Or symbolically: $A = Z + N$.

In nature there are four fundamental interactions at work. The first two namely, the *gravitational* and *electromagnetic forces* can be seen and most people are familiar with them. However, the other two forces, *strong* and *weak nuclear forces*, can only be seen at subatomic levels. In an atom, electrical repulsion repels like positive charge protons. At the same time the strong nuclear attractive force bonds protons and neutrons together. In order for the nucleus to remain stable, the nuclear force is many times greater than the electromagnetic one, but has a much shorter range limited to the nucleus as not to attract other protons.

One rather vital equation in the study of nuclear physics is the energy-mass relation formulated by Albert Einstein. It states: the energy (**E**) of a particular mass, is equal to the product of its mass (**m**) and the speed of light (**c**) squared.
In other words: $E = mc^2$. In atomic physics there is a unit of mass, the atomic mass unit, approximately equal to 1/12 of the mass of a neutral carbon atom.

$$1 \text{ u} = 1.66054 \times 10^{-27} \text{ kg}$$

The energy equivalent of 1 u would thus be:

$$E = (1.66054 \times 10^{-27}\text{kg})(2.99792 \times 10^{-8}\text{m.s}^{-1})^2$$
$$= 1.49242 \times 10^{-10} \text{ J} = 931.494 \text{ MeV}$$

eV - electron volts, a unit used to equate the kinetic energy of a moving particle.

$$1\text{eV} = 1.602\ 176\ 53\ (14) \times 10^{-19}$$

What is fusion?

Throughout the universe, fusion is the process that powers the sun and all other stars.
It is thus the core of our universe and probably the greatest energy source known to man.
In nuclear fusion, two light "parent" nuclei fuse together to form a heavier "daughter" nucleus. For example: two light-nuclei such as Deuterium (H^2) and Tritium (H^3), [both isotopes of hydrogen] fuse together to form helium-4. In this reaction the mass of the helium nucleus is less than the combined mass of the two parent nuclei, thus the lost mass, a neutron, has been converted into a neutrino and kinetic energy (heat). What makes fusion so amazing is that no radioactive elements are involved; this means it is

much safer than nuclear fission. It also produces five times the energy released by the fission of Uranium. The key to unlocking this holy grail of energy lies with plasma.

$$\mathbf{H^2 + H^3 \rightarrow He^4 + \nu_e + 17.6\ MeV}$$

Plasma is also known as the fourth state of matter. When an atom is heated, its electrons achieve a higher rate of spin. In a plasma, an atom is heated to the point at which the electrons spin so fast that the electro-static fields break. What this essentially means is that the forces that prevent nuclei from fusing together - the forces that cause nuclei to repel one another – fall away. Various forms of plasma are found on earth and in the universe, examples include:

- **Artificial plasmas** : neon & fluorescent lights; the electrical arc in welding; plasma globes; Fusion-energy research
- **Natural plasmas :** in a flame; lightning; the sun

The problem essentially lies in the fact that in order to achieve the state of plasma required for Deuterium-Tritium fusion, a gas needs to be heated over several million Kelvin, over 100 million Kelvin to be exact. This means that the use of a conventional reactor vessel is quite impossible. Currently nuclear physicists are employing two methods to overcome this issue. Generally there are two types of techniques that can be used to hypothetically create fusion On the one hand we have "hot" fusion which is created in an environment of over 100 million Kelvin, and on the other we have "cold" fusion which can be induced at room temperature.

Of the various "hot" fusion techniques, magnetic confinement fusion is currently on the forefront of fusion research. This technique uses a magnetic field created by super-conductors to insulate the plasma field and in this way it safely transports the plasma throughout the reactor vessel. The most successful examples include: the JET (Joint European Torus) and the MAST (Mega-Ampere Spherical Tokamak). Both these reactors utilize a Tokamak, in which the reactor vessel is in a torodial (ring-like) form. The plasma is kept away from the vessel walls by the aforementioned magnetic field. Initially the plasma is heated by using strong magnetic and then it is sustained by using RF (radio frequency)-heating. Although these two reactors have enjoyed various successes, they still use a lot more energy to heat and sustain the plasma than they get out of it. Another "hot" fusion technique is that of inertial confinement in which a high-intensity laser is used to fuse nuclei together.

Then we get the highly controversial theory of cold fusion. While normal "hot" fusion requires an environment in excess of a 100 Million K, the hypothesis of cold fusion states it is possible at much lower temperatures. Thus it requires much less energy to initiate the reaction and so is an attractive option for generating power. The only problem lies with the fact that it is yet to be conclusively proven.

Fuel cycles

There are various fusion reactions that can take place inside of a fusion reactor. Of all the elements, hydrogen (also the most abundant) is the easiest to fuse as it has the lowest nuclear charge and thus requires the least amount of temperature. Therefore most fusion reactions involve the different isotopes of hydrogen.

Deuterium-Tritium

Of all the reactions, the Deuterium-Tritium cycle is the most beneficial for generating power as it requires the least amount of energy.

$$H^2 + H^3 \rightarrow He^4 + n + 17.6\ MeV$$

The problem with the D-T cycle is that neutrons produced will eventually end up hitting the reactor vessel, which in turn will turn radioactive. Tritium used in this reaction is also a radioactive isotope and will require specialist handling. The production of Tritium is also dependant on the abundance of Lithium, which is significantly less than Deuterium.

The neutron-flux in a D-T fusion reactor is about 100 times greater than that of an average fission reactor. This means that a lot of neutrons are going to hit the containment vessel and turn it radioactive. In fact after only one series of D-T tests at the JET reactor, the vacuum vessel was so radioactive that they had to use remote-handling the following year. Of course an advantage of the large amount of neutrons is that they are utilized as a medium for conducting heat from the reaction, so that it can be converted into steam.

Other fuel cycles

Deuterium-Deuterium:

$$H^2 + H^2 \rightarrow H^3 + H^1 + 4\ MeV$$

$$H^2 + H^2 \rightarrow He^3 + n + 3.3\ MeV$$

Helium-Deuterium:

$$He^3 + H^2 \rightarrow He^4 + H^1 + 18.3\ MeV$$

Proton-Boron:

$$p + B^{11} \rightarrow 3He^4$$

Factors that influence fusion

Temperature – The higher the plasma’s temperature the more kinetic energy they have to overcome the electric repulsion forces

Density – the denser the plasma the higher the probability of atoms colliding and fusing together

Containment – Since no material can hold the plasma, it needs to be confined. Magnetic and inertial confinement are two ways of doing this.

Confinement time – this is the time it takes for the plasma's heat to radiate from the reactor vessel. The longer this is, the more reactions can take place.

Breakeven and Lawson product

Scientists measure their progress in fusion research by using the Lawson product. Currently scientists hope to reach the point of breakeven, this is when the energy gained from the fusion reaction equals the energy required to initiate and sustain it.

The Lawson product is briefly the plasma density times the confinement time at a given temperature. When the product is large enough, the reaction surpasses the point of breakeven.
Example: for a Deuterium-Tritium cycle, Lawson product is:

$n*t > 10^{20}$ sec/m^3 (n is the particle density and t is the confinement time)

Nuclear Fission

Fission is a nuclear reaction that occurs when a highly unstable nucleus is split into two daughter nuclei by a neutron. The mass of the two daughter nuclei is less than that of the original nucleus, thus the difference has been converted into kinetic energy.

Of the approx. 2500 nuclides known, less than 300 are stable. The greater the atomic mass of a nucleus, the greater the imbalance between the electric and nuclear forces. In a uranium-235 atom, the radius is much larger than the average atom; the radius is 7,4 times the range of the nuclear-force. This causes the Uranium nucleus to be highly unstable and over time eject an alpha particle (Helium-4) in the form of alpha decay, the other possibility being in the form of beta decay. In beta-minus decay a neutron is converted into a proton while at the same time both an electron and anti-neutrino are ejected:

$$\mathrm{n} \rightarrow \mathrm{p} + \mathrm{e}^- + \bar{\nu}_e$$

Whilst in beta-plus decay a proton is converted into a neutron, a positron and neutrino are emitted:

$$\mathrm{p} \rightarrow \mathrm{n} + \mathrm{e}^+ + \nu_e$$

In the mechanics of nuclear fission power a moderator is needed to iniated the reaction. A moderator is simply something that slows neutrons down so that a target nucleus will “accept” them, become unstable and split. In a light-water nuclear reactor, water is used as both moderator and coolant.

Nuclear fission has the advantage of being a clean energy source as it doesn’t generate any air pollution or worsen the effects of global warming. It produces lots of energy and could keep up with the demands of a large metropolis.

On the flipside of the coin it has some nasty disadvantages. As a by-product of fission, radioactive waste products are created, these need to be specially disposed and stored as they remain radioactive for thousands of years. Another disadvantage is that of thermal-pollution which is created when the cooling towers of nuclear power plants use nearby water sources, such as dams, to dump warm water in. Thermal pollution kills all the wildlife in these water sources.

Lastly fission plants have the knack of being a danger to public safety, the Chernobyl incident clearly illustrates this fact.

Hot Nuclear Fusion

Magnetic confinement fusion

Since fusion requires a plasma with temperature in excess of 10^8 K, a specially designed device is required in order to control this nuclear reaction. In 1951 scientists created the first controlled fusion reaction using a technique known as magnetic confinement fusion.

Modern MCF reactors use a Tokamak design in which strong electro-magnetic coils are set in a torodial (doughnut-shaped) form around a hollow chamber. The magnetic fields alter the movement of the plasma, restricting it to the confines of the chamber.

The MCF functions by first heating up the plasma to 20-30 million K using Ohmic heating. When a current passes through the plasma, the plasma has resistance and heats up. The only problem is that the hotter the plasma, the lower its resistance; thus we need more methods to further heat the plasma to fusion levels:

Neutral-Beam Injector – neutral, high energy, atoms are transferred into the plasma. In the process of being ionized, they transfer their energy (kinetic) towards the plasma.

Magnetic Compression – by increasing the magnetic field, the plasma is compressed and moves to a higher magnetic field, heating up in the process.

Radiofrequency Heating – high-frequency are fired at the plasma by use of oscillators. If they are of the right wavelength, their energy can be transferred to certain particles of the plasma, which in turn collide with others and transfer their energy.

Although fusion doesn't generate radioactive waste by-products as with fission, there is still an amount of radioactivity involved. The neutron flux, amount of free neutrons available, is estimated at over 100 times that of a PWR (pressurised water reactor) fission reactor. This essentially means that there exists a large of amount of neutrons which won't take part in the fusion reaction and will inevitably "hit" the containment vessel walls, which will turn radioactive.

The difference in fusion is that this radioactivity is much more stable and has a short half-life (period for ½ of the atoms to decay) of 10 years, whereas in fission the by-products are very unstable and have a long half-life in the thousands of years.

Inertial confinement fusion

Another proven method for nuclear fusion is that of ICF (Inertial confinement fusion). In ICF, a high-powered laser is used to heat a pellet containing Deuterium and Tritium. The laser burns the outer layer, creating a plasma and sending shock waves toward the centre. These powerful shock waves then heat the dense centre and initiate fusion reactions.
If this is done with perfect efficiency (highly improbable), a pellet the size of a pinhead would release as much energy as the burning of a barrel of oil.

Although billions have been spent on research in this field, laser physicists have yet to reach the breakeven point.

Cold Fusion

Electrolysis

On March 23, 1989, obscure chemists by the name of Stanley Pons and Martin Fleischmann made an astonishing and highly controversial claim of having produced fusion at room temperature, in a simple electrolytic cell. The implications of their findings were immediately felt worldwide as it appeared on every newspaper's front page.

Their simple electrolysis consisted of a palladium cathode and a platinum anode, submerged in a Dideuterium oxide solution. Their hypothesis was as follows: the palladium cathode, having the ability to absorb large quantities of Deuterium, has a large build-up of Deuterium during the process of electrolysis. The D_2 (Deuterium gas) is so densely packed together that it overcomes the columb-barrier and then fuses together.

Although the initial replication experiments were successful and reported excess heat, later experiments failed to achieve the claims of fusion. After more and more scientists retracted their claims of cold fusion, the world agreed that Pons and Fleischmann had made a mistake.

Only a group of diehards still backed the idea of cold fusion and continued their research. They blamed the failed tests of others on poor methodology and guidelines set by Pons and Fleischmann. Among these was a Japanese associate professor, Dr. Tadahiko Mizuno, who had over 20 years experience in the field of electrochemistry. Mizuno had replicated original CF experiment and set upon improving it by utilizing a much higher input voltage and current, which is known as plasma electrolysis.

Plasma Electrolysis

When electrolysis is done at a very high voltage, it usually results in a current overflow around the cathode, known as an electrical arc. Cold fusion scientists such as Mizuno and Ohmori performed plasma electrolysis experiments and witnessed anomalous generation of hydrogen and heat. They explained that the only possible answer could be cold fusion.

On 22 April, 1991, Mizuno's electrolytic cell, after being disconnected, begins to spontaneously heat up. Ten days later, after having evaporated 37,5 litres of water, the cell finally cools down.
The total kinetic energy generated:
(It takes 2260J/1g to vaporize water) 37500 x 2260 = 84750000 J or **8,475 x 10^7 J!!!**
Mizuno stated that the cathode was loaded with dense Deuterium that iniated and sustained a fusion chain-reaction.

Nobody has since achieved such a result.

More recently, a fellow by the name of Jean Louis Naudin had replicated his own CF experiment based on Mizuno's, but using tungsten as the cathode. He claims to have achieved astounding results that sometimes exceeded 200% output energy.

All his experiments are conducted openly and results are published on his website, although he too, is yet to replicate Mizuno's spectacle. He is also yet to publish a scientific paper. Since inception, Naudin's website has prompted the rebirth of CF. Now many others claim to have replicated Naudin's experiment.

Sonoluminescence

In 1989, Felipe Gaitan and Lawrence Crum, postualated that temperatures of over 10^6 K could be created in single bubble sonoluminescence (or SBSL). In their experiments, a single bubble is hit by intense ultra-sound waves. The bubble is first seen to expand and then collapse (as the gaseous cavity collapses) emitting bright flashes of light.

In 2003, Dr. R. P. Taleyarkhan, suggested that if such high temperatures are possible, SBSL could be utilized to induce fusion. In his experiments he produced single bubbles in a solution of deuterated acetone. He had apparently shown measurements of Tritium and excess neutrons, elementary proof of fusion. After independent groups tests had failed to achieve excess neutrons above background radiation levels, Taleyarkhan's claims were dismissed. To this day Taleyarkhan believes it to be fusion.

Pyroelectric Fusion

It is a technique in which lithium tantalate ($LiTaO_3$) pyroelectric crystals are heated from −30°C to 45°C, a strong electric field is generated which can be used to accelerate a beam of inner Deuterium from a thin Tungsten probe tip. This results in some Deuterium atoms fusing.

Unfortunately, as it requires a lot more energy to initiate than is extracted from the reaction, it is unlikely Pyroelectric fusion will ever be utilized as a economical way to produce fusion energy. However it could be used as a neutron generator.

Muon-catalysed fusion

Muons could basically be described as heavy electrons. In muon-catlysed fusion, Deuterium and Tritium nuclei form together with muons. These muons orbit very closely to the nucleus, absorbing the positive charge of the protons and allowing them to fuse. The muons are then expelled from the fusion reaction and can then initiate other fusion reactions.

This type of reaction, like pyroelectric fusion, requires much more energy to initiate and sustain it. This coupled with the fact that muons have a very short life of 2.2 microseconds, as they are very unstable, means that this also would be a impractical way of creating fusion.

Anomalous heat production by plasma electrolysis of light water – based on Mizuno & Ohmori experiments

Abstract

In a high-voltage, high current density electrolysis experiment, the formation of plasma around the cathode region was observed. Anomalous amounts of excess heat were also observed on several occasions, though a pattern could not be established. The transmutation of tungsten is hypothesised although this cannot be verified without the use of mass-spectroscopy.

Aim

To replicate a LENR (low energy nuclear reaction), cold fusion experiment, based on experiments done by T. Ohmori, T. Mizuno and JL Naudin. To test their hypothesis of fusion by:
1). Measuring the input and output energies and calculating whether excess energy is generated
2). Observing whether a plasma is created around the cathode area

List of Apparatus:

- 500ml glass beaker with wooden lid – reactor vessel
- 2.4 mm x 150 mm tungsten TIG welding rods – cathode
- 1.5 mm x 12 mm x 150 mm 304 stainless steel plate – anode
- 1 kVA DC transformer set to approx. 250V 4A output – power supply
- 2x Fluke 187 True RMS Digital Multimeters – to measure average current and voltage, i.e. power input
- Fluke temperature probe – to measure temperature difference after test run
- Soehnle Venezia electronic scale – to measure mass difference after test run
- $NaHCO_3$ – Sodium Hydrogen Carbonate – for electrolyte solution
- K_2CO_3 – Potassium Carbonate – for electrolyte solution
- Aqua Purificata – Distilled water – for electrolyte soltution
- Panasonic DMC-LC33 digital camera – recording video and photographic evidence
- Shunt resistor 1A = 1mV
- Shunt resistor 25A = 50mV – measuring currents in excess of 10A
- Casio fx-82TL Scientific Calculator – calculations

- Personal Computer – Data capturing
- Stopwatch – recording experiment duration
- Electric cordless kettle – pre-heating of electrolyte solution

Methodology

1. Firstly the experiment was set up as specified by diagram, using tungsten rod as cathode and stainless-steel plate as anode
2. The electrolyte solution was prepared: distilled water with correct molarity of either $NaHCO_3$ or K_2CO_3 according to specified test
3. The electrolyte solution was pre-heated to approx. 323 K (50°C) using a kettle. This is to lower the overall resistance of the electrolyte solution in order to successfully generate a plasma
4. Initial mass and temperature of the reactor vessel must be measured
5. Thereafter the wires should be connected to the electrodes
6. The power supply is then started and the duration of the experiment, average input power and video evidence is recorded.
7. The power supply is then stopped and wires are then disconnected
8. The resulting mass and temperature of the reactor vessel are then recorded
9. Data is then captured and the efficiency of the test is calculated

Calculations:

1) Input: Avg. current (I) x Avg. Voltage (V) = Avg. Power (J/s)
→ Avg. Power (w) x duration (s)
= Total electrical energy input (J)

2) Output: Difference in mass ($M_1 – M_0$) = H_2O vaporised
→ H_2O vaporised x 2260 J (H_2O heat of vaporisation)

Difference in temperature ($T_1 – T_0$) = increase in H_2O temperature
→ Increase in temperature x 4.18 J/g (H_2O heat capacity)

Total kinetic energy output = (H_2O vaporised) + (rise in H_2O temp.)

3) Efficiency:

Output energy (electrical) / input energy(kinetic) =
Power efficiency of reaction

Results:

Conclusion:

Both plasma and excess heat were observed during experiments, as hypothesised in Mizuno et al. scientific papers. Results varied greatly and no apparent pattern could be established, no factors influencing results could be found, although it would appear that a lower current density provided better results.

Furthermore I believe that if fusion was at work, the resulting efficiency would have to be in the range of approx. 10 – 20 times the input energy. Mizuno & Ohmori have only once observed such a result and no conclusive evidence were recorded to prove this.

I am unsure of the identity of the white residue found at the bottom of the vessel; my initial hypothesis was that of WO_4, it could well be transmutated tungsten.
One question remains: has nuclear transmutation taken place?

Main Conclusion

In consideration of all my research I have come to the following conclusion that the world certainly is at an energy crisis. The need for a new sustainable energy source is very urgent indeed. Nuclear fusion presents a hopeful solution to this problem, but we are far from being able to utilize it. Our lack of understanding in fusion reactions limits our ability to benefit from it.

MCF reactors seem to be our best bet in generating power. Yet a great deal of research still needs to be done in order for it to succeed. The newly proposed ITER reactor will be a giant leap in the field of fusion research.

Whilst Cold Fusion appears to be the answer for some, it is mere wishful thinking to most and no one has conclusively proven the theory yet. In my own experiments I had measured excess heat on several occasions, but could not establish factors that influenced my results. I couldn't test for neutrons or gamma-radiation, as I don't have the necessary equipment, so nuclear reactions cannot be ruled out. My hypothesis is that there is another, unidentified Low Energy Nuclear Reaction at play, a form of fusion requiring much less energy to initiate, but also producing much less.

It is my hope that mankind will one day harness the power of the sun. As a scientist I also one day hope to join the search. I firmly believe that fusion indeed, is the future.

Bibliography

In my research the following sources were utilized as reference:

- Wikipaedia - en.wikipaedia.org
- Iter's website – www.iter.org
- Jean-Louis Naudin website - http://jlnlabs.imars.com/cfr/
- International fusion website - www.fusion.org.uk
- JET fusion reactor website - www.jet.efda.org
- ThinkQuest website - http://library.thinkquest.org/
- MAST UK fusion test reactor – www.fusion.org.uk/mast/index.html
- Spherical Tokamak – www.fusion.org.uk/st
- START fusion reactor – www.fusion.org.uk/start
- Google search engine – www.google.co.za