HEAD-ON COLLIDING HYDROGEN PLASMA FUSION
A PROPOSED WORKABLE HYDROGEN FUSION GENERATOR

BY

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Abstract

This paper describes a novel method of achieving practical hydrogen fusion. What is proposed is that two plasma streams of hydrogen having a high density and a large cross-section are fired at each other, head-on, at a high speed. At a certain point, nuclear fusion will occur. The design of this device allows extraction and utilisation of the heat produced.

When protons collide at a sufficient velocity, with the required high plasma density and large plasma cross-section, some of the protons fuse into helium nuclei, generating heat. If the plasma density and cross-section are large enough, the required velocity can be relatively low and is technically feasible. The so-called Lawson Criterion describes this trade-off. The Maxwell-Boltzmann tail effect combined with the Quantum Mechanical tunnelling effect reduces the required velocity further to an achievable level.

These plasma streams are accelerated to high relative velocities by a novel plasma acceleration device, also described in this article. This device also allows the stream of plasma to have a high enough density and cross-section, so that the required relative velocity of the plasma can be relatively low. The device consists of two plasma accelerators firing plasma at each other. Each of the accelerators consist of a tube surrounded by a large number of individual electro-magnetic coils, each connected to a power supply. The electro-magnetic field of each coil is varied so that a magnetic 'pocket' is created. Each pocket holds a packet of plasma. The magnetic fields of the coils are varied so that each pocket is accelerated up the tube to a high velocity, carrying the packet of plasma with it. These packets of plasma are ejected out of the tubes and fired head-on at each other. If these plasma packets are of sufficiently high relative velocity, density and cross-section, hydrogen fusion will occur.

Plasma fusion can be generated continuously using this device. The heat generated can be utilised by injecting water into the location where fusion occurs, and the resultant steam generated can be used to generate electricity.

A single plasma accelerator can be used to accelerate plasma to a high velocity, for a variety of purposes such as propelling a space ship.

Background on the history of plasma fusion activities to date

For over fifty years increasing efforts have been aimed at attaining net energy output using hydrogen fusion generation – that is, more energy is generated than is put into the process of hydrogen fusion. For the entire period these attempts have not succeeded, and no significant useful net energy output has been generated (Kikuchi 2010). The method invariably used is the so-called Tokamak, first invented by the Russians Igor Tamm and Andrei Sakharov in the 1950’s (Shafranov 2001).

The Tokomak can be described as having a doughnut shape, or is described as a torus. It is constructed of multiple magnet coils wrapped around this doughnut, these coils surrounding a vacuum. An intense magnetic field can be momentarily generated with these coils in this central space. Into this vacuum is injected deuterium in plasma form, that is the gas is heated to a very high temperature so that the deuterium gas loses electrons, and becomes electrically conductive. This is done in order to contain the plasma in the torus by magnetic containment. An intense magnetic field is momentarily applied to squeeze the gas to an intense pressure and raises the temperature (a higher temperature and pressure than inside the sun). At this moment some of the deuterium gas fuses into helium through the process of nuclear fusion.

The problems with this process are as follows:

1. This fusion process can only take place for a fraction of a second. If the magnetic field holds the plasma for longer, the plasma in the torus becomes unstable and destroys the Tokamak. Fifty years of experiment and every larger Tokamaks have not solved this basic problem.
2. The energy used to create the momentary fusion far exceeds the energy produced by the fusion.
3. No way has been found to extract the energy produced by the fusion from the Tokamak. Even holding the fusion for a longer time does not solve this problem. The Tokamak is essentially a useless experiment for the practical purpose of energy extraction.

Why do the experimenters continue with this activity? The major reason is that the potential prize of nuclear fusion makes activity worthwhile. The potential benefits of nuclear fusion - cheap, inexhaustible, no-polluting energy are so great, it means that almost any amount spent on this quest is worth it.

The structure and contents of this paper

This paper describes an alternative and feasible method of obtaining hydrogen plasma fusion, without using the Tokamak. This method uses head-on impact of a sufficiently large volume of hydrogen plasma at high speed and high density. This method described is theoretically correct, practical, and efficient.

This paper is divided into two parts:

1. A theoretical explanation of hydrogen head-on colliding plasma fusion.
2. An explanation of a practical method to generate continuous hydrogen plasma fusion, and a method of continuously tapping this heat generated.

Part 1. The theory behind head-on colliding hydrogen fusion

At the fundamental level, for two nuclei to fuse, they have to cross the coulomb barrier around the nucleus. Outside the coulomb barrier two approaching nuclei are pushed apart by very strong forces of electrostatic repulsion. If the nuclei cross the coulomb barrier, atomic forces of attraction take over and overcome the forces of electrostatic repulsion, and draw the nuclei together. The nuclei collide and fuse into a different and larger nucleus, releasing energy and particles. (Strictly speaking nuclei of increasingly heavy elements can be fused until iron atoms are reached, when fusion ceases. This is the so called 'packing fraction' phenomenon, but this need not concern us here).

The coulomb barrier is measured in energy levels. The unit is Kelvin or K.

Deuterium nuclei have a coulomb barrier of 4×10^{8} K.

Hydrogen nuclei have a coulomb barrier of 1.5×10^{7} K.

Simple arithmetic shows that the coulomb barrier for hydrogen nuclei is 30 x less than that for deuterium. Yet the Tokamak experiments use deuterium and even heavier stuff like tritium. Why is this?

The reason is that getting hydrogen nuclei (which is a single proton) to fuse is not all that simple. There are actually three steps to a proton-proton reaction. These are:

1. A pair of protons fuse, forming a deuteron. (The nucleus of a deuteron).
2. The deuteron fuses with an additional proton to form helium-3.
3. Two helium-3 nuclei fuse to create beryllium-6, but this is unstable and disintegrates into two protons and helium-4.

The last reaction *also* releases two neutrons, two positrons, gamma rays, and a great deal of heat. This whole phenomenon is observed by astrophysicists in core of our sun. In the sun, the helium-4 nucleus is stable at that temperature and picks up the excess electrons.

On the other hand, the deuterium-deuterium reaction is just one step, also producing helium and a large quantity of energy.

This is where the role of probability steps in. Compared to deuterium, which is a one-step reaction, the hydrogen-hydrogen reaction is a three-step reaction and thus has a lower probability of completing all the steps. For the reaction to have the likelihood to complete all the steps, the atoms need to be very close together, so the hydrogen plasma needs to be very dense, and also the cross-section of the plasma must be sufficiently large.

The sun for instance, where this hydrogen-hydrogen reaction takes place, has a very high internal pressure and density sufficient for this multi-stage reaction to take place. And of-course it is very large.

These theoretical and practical requirements are encapsulated in the Lawson Criterion, and its “Triple Product”. Without going into the math, the likelihood of a fusion reaction depends on the density of the plasma, the temperature or energy of the plasma, and the confinement time, which is the rate at which the system loses energy to the environment. The latter confinement time is in turn a function of the volume of the plasma. The greater the volume of the plasma, the greater the confinement time.

Thus, in effect the likelihood of fusion depends on two three things”

1. The temperature of the plasma
2. The density of the plasma, and
3. The volume of the plasma packet.

Another way to define the temperature of the plasma is to define it as the relative velocity of the individual particles. The velocity of the individual particles can be estimated from the mass of the particles and the energy of the individual particles.

As every physicist knows this energy is actually kinetic energy – the energy a particle gains from velocity. In fact, a high temperature is manifested in a gas by the high speed of the individual particles – the higher the speed the higher the energy.

What is the relative velocity required for two colliding protons to fuse?

What is the velocity required for a proton-proton nuclear fusion reaction to be achieved?

For two single protons to fuse you need to overcome the Coulomb repulsion between them. This gets stronger and stronger as they approach each other. For two protons to collide and fuse head on they would theoretically need a closing velocity of 20 million metres a second (7% of the speed of light). Corresponding to a temperature of 5 billion degrees. Yet our sun manages to do it with a temperature of 16 million degrees. How? It is all to do with pressure and the confinement time, The Lawson Criterion, as well as the so-called Maxwell-Bioltzmann tail and the Quantum Mechanical tunnelling effect.

Some of the protons on the tail of the velocity distribution curve do have the requisite energy. And the more of them in close quarters, the greater probability of a sufficient number crossing the coulomb barrier. This tail is called the Maxwell-Boltzmann tail.

Also, the so called “tunnelling effect”, due to the quantum mechanics, greatly increases the probability that the protons will cross the coulomb barrier and fuse.

So, the answer to the question – what is the minimum velocity required for fusion?

There is no single velocity. The greater the density and volume of the plasma, the lower the velocity required. The answer to this question lies within the area of experimental physics.

The Gamow Peak

After this description of the theory; the velocity, density, cross-section, and the tunnelling effect all come together so that, that in the sun at least, protons can fuse with energies of 6 KeV or less. (See the above values of the coulomb barrier for hydrogen).

There is an excellent little article that explains this on burro.cwru.edu/academics/Antr221/StarPhys/Coulomb.html that explains that under the right conditions (ie at the centre of the sun), you can get a peak of hydrogen fusion at 6 KeV energy of the proton. This is the Gamow Peak. You can get fusion at much less energies. This phenomenon occurs when the effects of the Maxwell-Boltzmann tail and Quantum Mechanical tunnelling combine.

The velocity of each particle in this case is around 1600 kms per hour. Thus, hydrogen nuclear fusion is well within the region of feasibility, given sufficiently high density and cross-section.

The velocity required is a matter of experiment

Is the velocity required in the device likely to be high? No. The device to be described can be used to vary the quantity of plasma entering the device, the density of the plasma packet, as well the velocity of the plasma. These variables can be varied together with the aim of achieving an optimum output of heat from the fusion process. A high density can be achieved with this device, together with a relatively high volume. The achievement of nuclear fusion is a matter of experiment, but given the high number of protons being fired at each other, and the high levels of density and volume of the plasma can be achieved, together with the quantum effects, it is near certain that feasible nuclear fusion will be achieved.

Incidentally, while there have been many beam experiments, firing protons at each other head on. As experiments, they have successfully achieved nuclear fusion. But as the proton hits have been numerically very small, this has never been a practical method to achieve nuclear fusion. However, the lesson to be taken from these experiments is that successful fusion was achieved with a relatively low relative velocity of collision. Recently, the LHC has performed low energy 450 GeV collisions between protons in the process of setting up the high energy experiments, and achieved fusion.

Part 2. Description of the hydrogen plasma accelerator

The primary aim of this device is to accelerate two high volume sets of hydrogen plasma to a high speed, aim these jets of plasma head-on at each other so that the individual protos collide, and generate nuclear fusion. As the same time a high density of the plasma must be maintained while the protons collide. These three requirements acting together enable nuclear fusion.

The device at its basic level would consist of two plasma accelerators, pointing at each other. Plasma, a heated and electrically conductive gas, would be accelerated along both these accelerators to a high speed. This relative velocity can be varied according to the degree of plasma fusion achieved, given the plasma density being achieved in the accelerator.

I have invented a plasma accelerator to do this combined task of accelerating the plasma to a high velocity, and at the same time maintaining a high plasma density. This accelerator has been patented, but this patent has been allowed to lapse. Anyone can now use the design for free.

As described in this now lapsed patent, this plasma accelerator can also be used as a rocket drive in space, as huge acceleration can be generated using little mass.

At this point I would advise experimenters that care should be taken in the experiment, as a large reaction force would be created by the accelerating plasma. A careful solid design of all the components used is a necessity.

Essential features

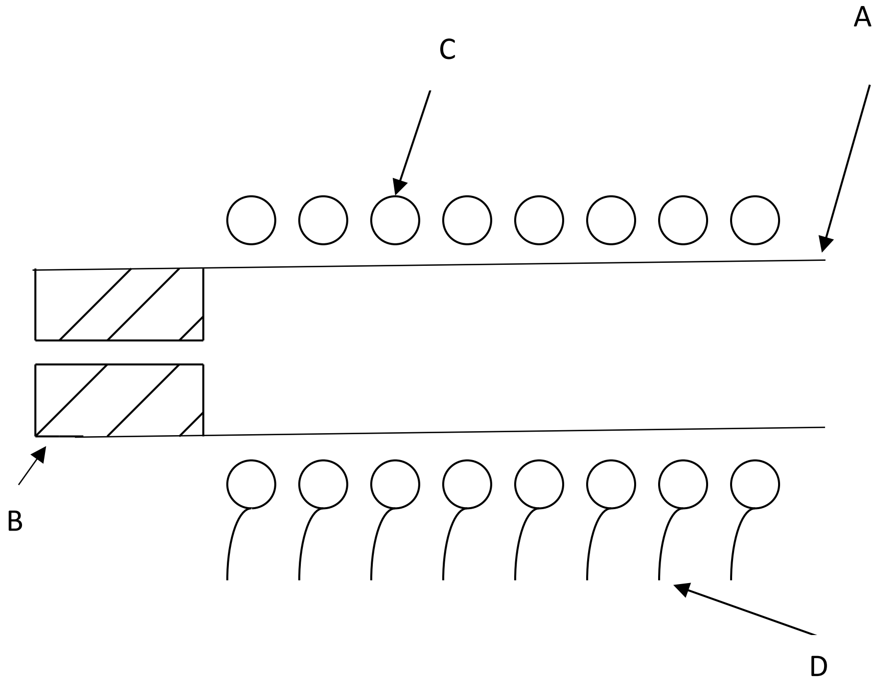
The essential feature of this device is shown in Diagram 1, a long straight tube marked (A). There are two of these tubes. The dimensions of these tubes are undefined. The length of each tube shall be long enough so that the plasma inside it can be accelerated to the required velocity. The diameter of each tube should be small enough so that an intense magnetic field can be generated inside the tube without unnecessary power consumption, so that a high density of the plasma can be achieved, yet large enough volume to contain sufficient hydrogen plasma to fuse on collision with another hydrogen plasma stream.

Vacuum required if hydrogen or deuterium is used

If hydrogen or deuterium plasma is used the tubes should contain a vacuum, because otherwise the hydrogen or deuterium plasma would react with the oxygen in the air.

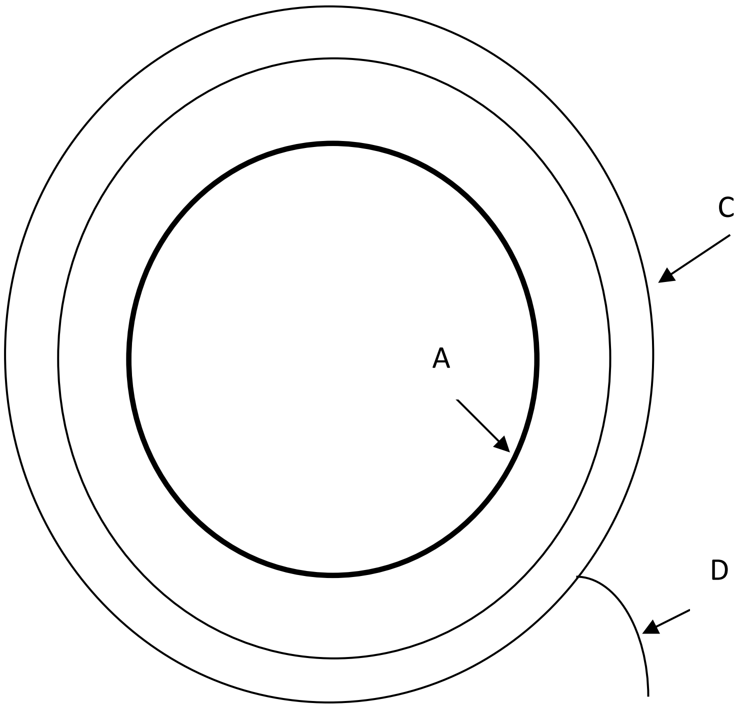
At one end of the tube is a device that heats gas into a plasma, marked (B). This plasma heating device is not defined here, but it will be able to feed heated plasma into the device continuously. The author suggests a simple device such as a plasma welder, which can work very effectively.

DIAGRAM 1. THE BASIC PLASMA ACCELERATOR TUBE



Around the tube is wound numerous independent and electrically unconnected electric conducting coils (C), each capable of generating an intense magnetic field. Each coil has a separate electrical source (D). These electrical sources are connected to a commutator that vary the current in each coil in a cyclical manner in order. A coil surrounding the tube is shown in a plan view of the tube in Diagram 2.

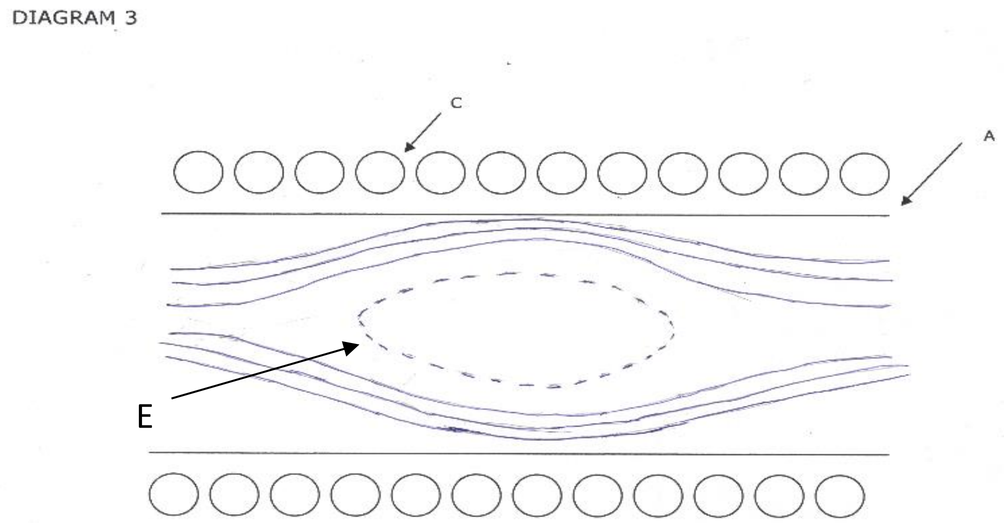
DIAGRAM 2. PLAN VIEW OF MAGNETIC COIL



Each set of coils is connected to an independent power cable, each marked (D).

Each of these cables is attached to a power source, which can supply a sufficient amount of power to create an intense magnetic field in the coil. This magnetic field can be made to vary by varying the current separately in each coil, using a commutator or control device. The magnetic fields of each coil are varied in sequence so as to generate a ‘pocket’ of magnetic fields of varying strength, (E), as shown in Diagram 3.

DIAGRAM 3. MAGNETIC FIELDS OF VARYING STRENGTHS CREATING POCKETS TO HOLD PLASMA



By varying the currents in these coils, and thus the magnetic field, consecutively, the magnetic ‘pocket’ can be made to move along the tube. If this is done fast the magnetic pocket can be made to move fast along the tube. If the currents are varied slowly at one end of the tube, and varied at an increasingly faster rate progressing up the to be, the ‘pocket’ can be made to accelerate. The size of the pocket can also be changed as the pocket is accelerated.

The currents in the coils are varied in a sinusoidal manner. While the method for varying the current in a sinusoidal manner is not specified here, one method could be to use commutators for each coil. However more efficient methods could be used.

It could be mentioned in passing, other shapes for the electromagnetic fields are possible, such as flat or ‘block’ shaped fields. All these different types of fields can be made to accelerate up the tube by a suitable technical device not specified here.

The currents in the coils are varied at a faster rate progressively up the coils along the tube, so that the variation of current in the coils at one end of the tube are relatively slow compared to the variation of the current at the other end of the tube, which would be relatively fast. The variation of current in the coils in between would be progressively faster along the tube. Thus, there would be an appearance that the magnetic field **accelerates** up the tube.

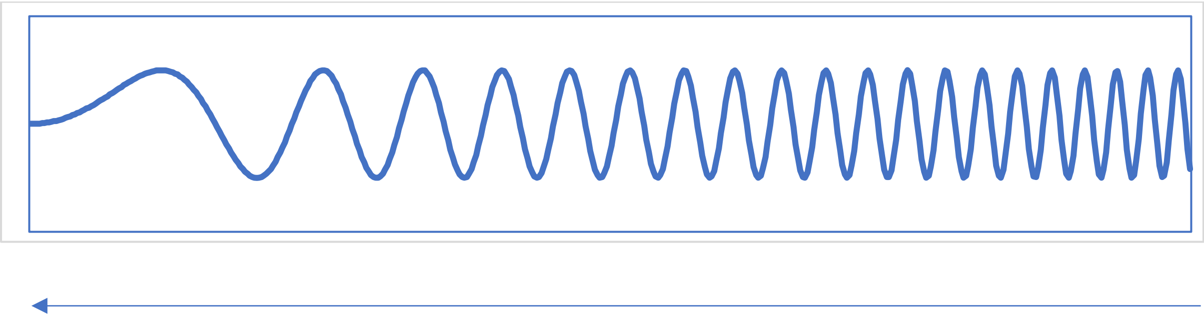
One rotation of the commutator is the same as one cycle of the magnetic field inside the tube.

This variation in the width of each magnetic cycle, and the variation its frequency at each position in the tube, is done by varying the connection of the coils with the commutator.

Although the commutator rotates at a constant speed for all the coils, the attachments from the commutator to the coils vary. At one end of the tube, the coil attachments are set over a relatively narrow area of the commutator's circumference. This would give the impression that at this point the magnetic field is moving relatively slowly up the tube. Progressing up the tube, the coil attachments are set wider and wider apart so that the magnetic fields vary faster. This gives the impression that the magnetic fields are accelerating up the tube.

Alternatively, the size of the coils get wider as they progress up the tube.

DIAGRAM 3   VIEW OF SINUSODAL WAVES AS THEY PROGRESS UP THE TUBE



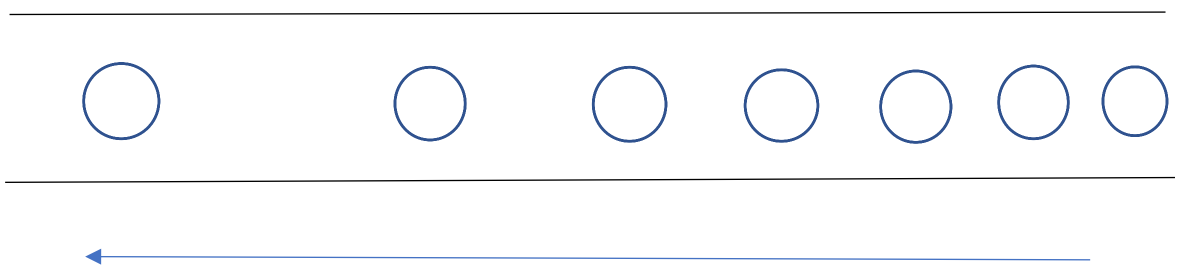
Direction of acceleration of wave

The equation for the above sinusoidal wave is $y = a \sin (bx^n)$. where y is the vertical axis and x the horizontal axis; increasing a increases the amplitude or height of the wave, increasing b increases the period or frequency of the wave, and increasing n increases the rate at which the waves widen as they go up the tube, or in other words, increases the acceleration of each package of plasma. In this machine the rate at which the waves widen has to be hardwired into the commutator. The maximum rate of acceleration depends on the strength of the magnetic field and the size of the plasma package. These are engineering trade-offs within the device. Increasing the rate of acceleration of the plasma package can increase the final velocity of the plasma compared to the length of the tube, so increasing this rate of acceleration can reduce the length of the tube needed.

While all these factors are trade-offs, the optimal aim is to bring about a minimum relative velocity of the hydrogen plasma fired at each other from both accelerator tubes to initiate continuous hydrogen fusion.

If the plasma of heated gas is injected into the tube at one end, and if the magnetic field is strong enough to contain the plasma, the plasma can be held in the pocket by the electric field. See Diagram 4. The plasma is held in the magnetic field because the moving plasma itself generates a magnetic field that interacts with the magnetic field generated by the coils.

DIAGRAM 4 VIEW OF THE POCKETS OF PLASMA ACCELERATING UP THE TUBE



Direction of acceleration of the plasma pockets

This magnetic pinch effect also occurs in the so-called Tokakmak, where the magnetic field of the plasma is acted upon by the magnetic field in the Tokakmak torus which encloses the plasma. However, in the Tokakmak the plasma is more of less stationary and is not accelerated, as in the proposed device.

As the magnetic 'pocket' is accelerated, it drags the enclosed plasma along with it. This plasma in the 'pocket' is also then accelerated. Using this method, the plasma can be accelerated to a very high velocity, and the numerous very fast plasma 'pockets' look like a continuous stream of plasm. This plasma stream can be used for nuclear fusion by directing two very fast plasma streams of deuterium or hydrogen head-on at each other at a high enough velocity to fuse the respective deuterium or hydrogen into helium, and thus release large quantities of energy.

The acceleration of the plasma could also be used to power a space ship using very small quantities of propellant mass of any type of gas. Indeed, it could also be used as a weapon, using oxygen plasma, to shoot down missiles.

Incidentally, there is a practical problem with Tokamaks, the so called "Bohm effect". This is the high rate of leakage of the plasma through the magnetic field around the toroid. This Bohm effect is largely obviated by this tube accelerator, for the simple reason that the time the plasma remains in the tube is very small. A fraction of a second.

There is an additional design change with this device that can be used to concentrate the plasma, and greatly reduce then Bohm effect. If the plasma is also **rotated laterally** along the axis of progression along the tube, it would also generate a magnetic field that would concentrate the plasma to the centre of the axis of rotation. The Bohm effect would be greatly reduced. In order to rotate the plasma, the magnetic coils could be set at a slight angle to the axis of the tube. The angle of the magnetic field together with the direction of motion of the plasma should set the plasma to rotate. This rotation of the plasma in the magnetic field in order to induce stability is currently used in Tokamaks to induce stability – the so called 'safety factor'.

Practical application of the nuclear fusion device

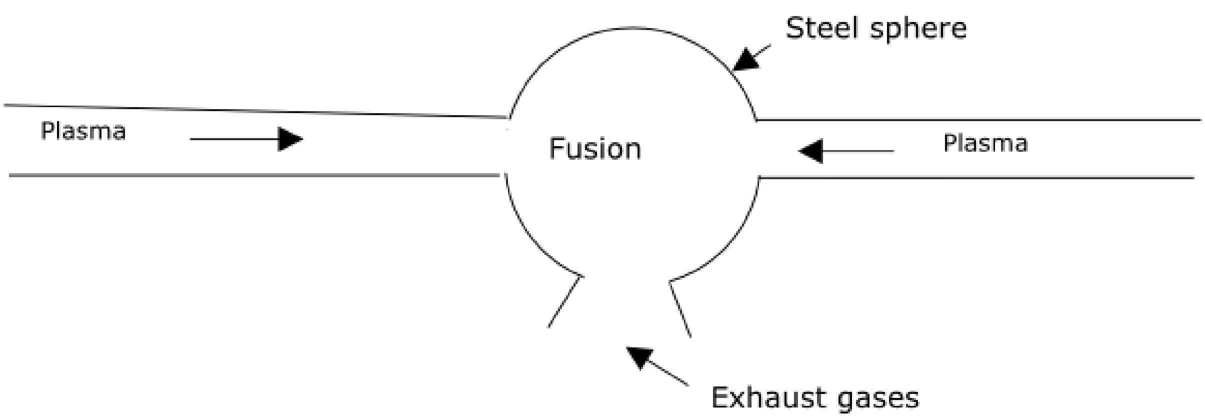
It is impossible to extract useful amounts of heat energy from the Tokamak. Even if the Tokamak is operated continuously, and continuously fed Deuterium, the Tokamak is not designed for feasible heat extraction.

However, conceptually, the proposed head-on plasma fusion device can be constructed to allow continuous generation and extraction of very hot steam. This steam could be used to generate electricity using standard steam turbines.

The method is described in concept in the following diagrams.

Diagram 5 shows the conceptual device. It consists of two tubes pointing at each other. These tubes are surrounded by many separate magnetic coils. At the end of each tube is a plasma generator. This plasma generator is not described, but it could be of standard form such as an arc welder. These tubes feed into a reaction chamber, where the nuclear fusion takes place. This reaction chamber is held at a near vacuum. Hydrogen or deuterium dense plasma is accelerated head on into the reaction chamber at a high enough relative velocity, so that nuclear fusion takes place.

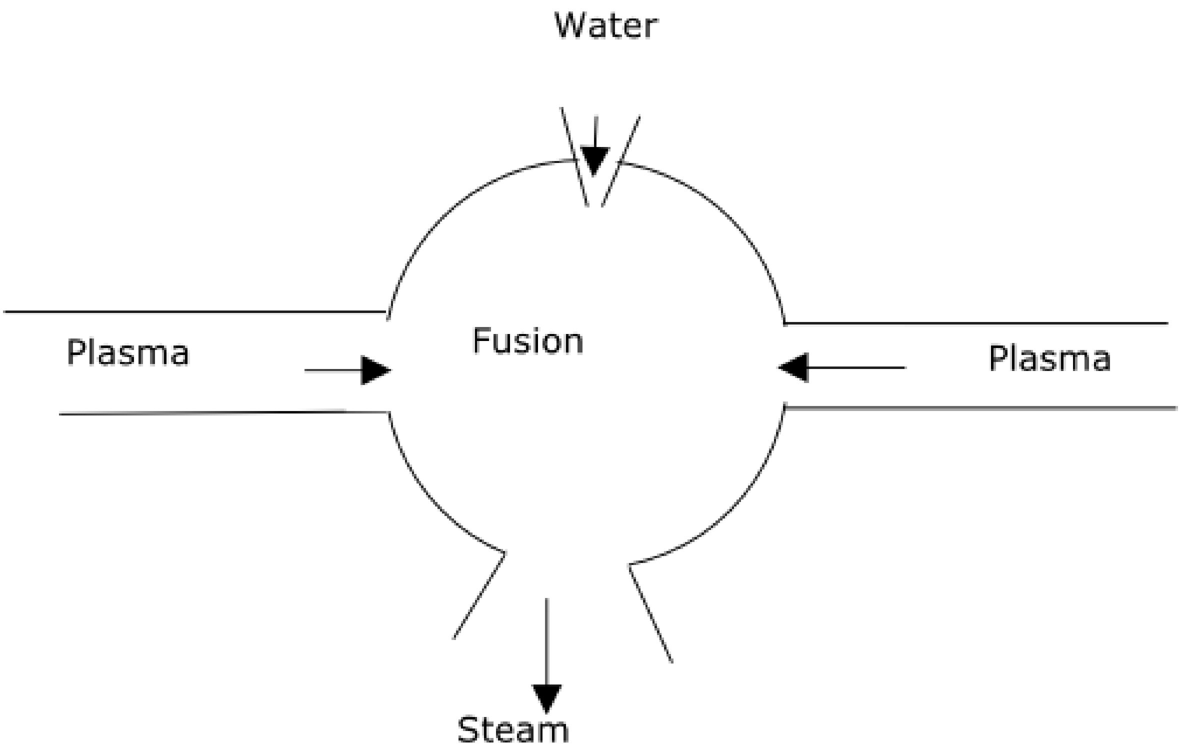
DIAGRAM 5. NUCLEAR FUSION DEVICE WITH PLASMA ACCELERATORS POINTING HEAD ON AT EACH OTHER



The rate of fusion can be detected by neutron and gamma ray detectors. Also, the gas in the reaction chamber can also be analysed for helium production.

While this diagram describes the standard components of a nuclear fusion device, it does not describe a method of extracting energy from the device. This is shown in conceptual form in Diagram 6.

DIAGRAM 6. EXTRACTING STEAM ENERGY FROM THE NUCLEAR FUSION DEVICE



Again, the two tubes direct plasma at high speed into the reaction chamber. But now there is an input into the reaction chamber, and an exit from the reaction chamber. The input sprays water into the reaction chamber. The nuclear fusion reaction heats this water into superheated steam, and this steam exits the reaction chamber to drive steam turbines that in turn drive electric generators.

This steam also removes the waste matter – helium and hydrogen. As these elements are non-radioactive they can be released into the air without harm. (Though it may be worthwhile to extract the helium).

Thus, hydrogen fusion is possible and relatively easy to accomplish. Using this device, it is also possible and relatively easy to continuously extract steam heat energy for the purpose of electricity generation.

Practical advice for building the device

Various stages

It is recommended that building this device should take place in stages:
(Extreme care should be taken with safety issues – including when fusion is achieved).

1. Build one tube with the electromagnetic acceleration coils to test if it functions correctly without plasma.
2. Test the tube with an inert gas plasma, to see if it accelerates the plasma to a high speed. (As the high-speed plasma is likely to penetrate walls, you would need to point the plasma at a thick target). This stage alone is a major useful achievement, as there could be many uses for this device alone.
3. Build a second tube and test if it functions correctly, without and with the plasma.
4. Point these two tubes at each other, and direct the inert plasma head-on at each other. Test at various velocities. (The inert plasma will not fuse).
5. Insert *each* tube in turn into a vacuum chamber, and test with hydrogen plasma.
6. Insert both tubes into the vacuum chamber. Surround with detection equipment for gamma rays and neutrons. Fire the hydrogen plasma head-on at each other, at a *low* speed at first, and *very slowly* increase the speed. If this does not work, increase volume and density. Be very careful, as tremendous energy can be released with very low levels of hydrogen fusion.
7. If you achieve fusion, try to extract energy at that level by injecting water and extracting steam.

Recapitulation

With the plasma acceleration device described here, large volumes and densities of hydrogen plasma can be continuously fired at each other in head-on streams of plasma at a high velocity. If the hydrogen plasma packets are dense and have a large enough cross-section, they will fuse at a relatively low velocity. The device can keep raising the velocity of the plasma stream until at some point nuclear fusion of some of the colliding protons is highly likely. The fusion can be maintained at this level, water injected at the point of fusion, and steam generated that can be used for electricity generation.

Summary

1. Hydrogen plasma fusion is theoretically possible, by colliding hydrogen nuclei protons) head on.
2. Low relative speeds can create hydrogen nuclear fusion if the protons are in a packet of protons of sufficiently high density and cross-section – as explained by the so-called Lawson Criterion.
3. Additionally, the required relative velocity is considerably reduced by the Maxwell-Boltzman tail effect and the Quantum Mechanical tunnelling effect.
4. An exact figure for the relative velocity required for fusion cannot be given, as it depends on the design of the apparatus, but given reasonable Maxwell-Boltzmann

and Quantum Mechanical tunnelling effects, it is quite feasible that fusion can be achieved with relatively low and technically feasible relative velocities.

5. There is a three-stage process for hydrogen nuclear fusion:
    a. A pair of protons fuse, forming a deuteron.
    b. The deuteron fuses with an additional proton to form helium-3.
    c. Two helium-3 nuclei fuse to create beryllium-6, but this is unstable and disintegrates into two protons and helium-4.
6. Such a high-speed collision of high-density hydrogen plasma can be ensured by using a plasma accelerator device described in this article, as follows:
7. The plasma accelerator consists of two long tube pointing at each other, and a device at the end of each tube to heat the hydrogen plasma.
8. The tubes are surrounded by individual and electrically independent coils, each of which are attached to cables leading to a variable power supply.
9. Electric current is passed successively through each of the coils to create a high intensity magnetic field inside the tubes.
10. The electric current is varied consecutively along the tube the vary the magnetic field to create a pinch effect or magnetic pocket.
11. A hot gas plasma of deuterium or hydrogen, or any other gas if the device is not being used to create fusion, is placed in the tubes at one end.
12. This plasma is held in a magnetic pocket generated by the magnetic coils.
13. The current in the coils is varied consecutively to create the effect of moving the magnetic pocket up the tube. The plasma contained in the tube is held in the magnetic packet and moves with the magnetic pocket up the tube.
14. The current in the coils is varied to accelerate the magnetic pocket, by varying the current in the coils progressively towards from one end of the tube to the other. The size of the pocket may be varied to increase the compression of the plasm in the magnetic pocket.
15. The plasma held in the magnetic pocket is also accelerated along with the magnetic pocket. This way the velocity of the plasma can be increased from zero to a very high speed from one end to the other.
16. Hydrogen or deuterium plasma, impacting at high speed and sufficient density and quantity, can be fused into helium and generate vast heat.
17. This fusion can be generated continuously by the continuous collision of the plasma.
18. If the hydrogen or deuterium plasma is fused in a reaction chamber, water can be sprayed into this chamber to be converted into very high temperature steam. This steam can exit the chamber and be used in a steam turbine to continuously generate electricity.
19. A single plasma accelerator can be used to accelerate plasma to high velocities for various other purpose.

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