IV. Fusion Primer—Part Three

'Minimum Energy' Configurations Can Make Superheated Plasmas

by Ned Rosinsky, M.D.

Sept. 17—*This is the third part of a four-part series on fundamentals of fusion and plasmas. Part I appeared in* EIR *Aug. 23, 2024 and reviewed the basic units of mass, length, time, force, work, and energy. It also included an introduction to electricity and magnetism, and a discussion of the electromagnet. Part II appeared in* EIR *Sept 20, 2024 and reviewed the creation of plasma vortex filaments as a magnetic bottle to contain plasma in a fusion machine.*

Introduction

Fusion involves the combination, or "fusing," of the nuclei of atoms of relatively light elements—such as hydrogen or helium—with each other, to produce enormous amounts of energy. The energy is produced when two small atomic nuclei combine to make a larger nucleus, and the mass of the new nucleus and other possible byproducts is slightly less than the initial mass of the two nuclei which fuse. Approximately 0.7% of the starting mass is lost in most types of fusion. If the energy is measured in joules and the mass in kilograms, then the energy produced is 90 million billion times the change in mass, which is the square of the speed of light in meters per second. The raw materials for many types of fusion are available and at low cost. The major problem is to bring nuclei together close enough and long enough for them to fuse.

The solution is to heat the fuel to high enough temperatures for some of the electrons to separate from the atoms, leaving the positively charged ions, or bare nuclei—a state of matter called a plasma. Under these conditions the nuclei are moving rapidly and they will crash into each other, and in some cases fuse, even though atomic nuclei are positively charged, and positive charges repel each other.

A plasma in a container will expand to fill the container, like a gas, but it is considered the fourth state of matter, after solids, liquids, and gases. The particles in plasmas usually move very freely in response to electric and magnetic fields, and they respond to electric and magnetic fields over long distances.

The plasma temperatures required for fusion are 100 million degrees Centigrade or higher, and this heat would destroy any ordinary solid container. But there are two possibilities for containment. First, a small pellet containing the fuel can be rapidly shock-compressed by lasers from all sides, causing the fuel to heat up, and fuse. This was done recently at Lawrence Livermore National Laboratories, which was the first time that a fusion experiment "broke even"—produced as much or more energy than was applied to compress the fuel. Second, magnetic fields can be arranged to contain the fuel at high temperatures without the fuel touching the walls of the container. This is called a magnetic bottle, and there are many designs.

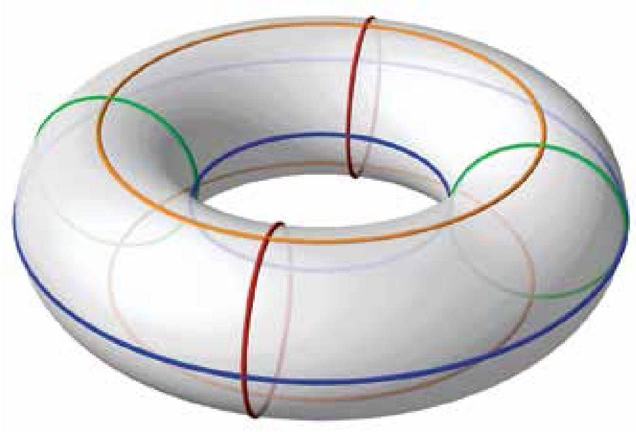
Vortex Filaments and Vortex Rings

In the important and fascinating example we discussed in Part II, the creation of *vortex filaments* in a plasma can result in the *spontaneous* formation of a magnetic bottle which can confine plasma so that it can be accelerated, condensed and sufficiently heated, potentially to provide fusion energy.

Sometimes the formation of vortex filaments is entirely spontaneous, but they can also be caused to form under certain conditions. The filament usually has a generally straight central axis, and consists of spirals of plasma currents and magnetic fields that circulate around this axis. These spirals can be measured by the angle they make with circles around the axis in a plane perpendicular to it. A spiral with a small angle has many closely-spaced turns. A spiral with an angle approaching 90 degrees barely rotates as it moves parallel to the filament axis.

On the outer surface of the filament, the currents and magnetic fields are actually in circles, not spirals.

FIGURE 1
The Torus



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The torus is a donut-shaped surface. A torus has two main directions for moving around on its surface, termed toroidal *and* poloidal. *The blue circles are in the toroidal direction, the long way around. The red circles are in the poloidal direction, the short way around.*

Below the surface, the currents and filaments have small spiral angles, which increase for deeper layers of the filament; near the axis, the spiral is nearly a straight line parallel to the axis. The spiral paths of electric currents, and of magnetic fields, are either parallel (same direction) or anti-parallel (opposite direction). Because of this, there is no magnetic force exerted on the electric currents (described as "force-free").

Vortex filaments are usually very short-lived, disintegrating after several milliseconds. Winston Bostick, the scientist who discovered them in the 1960s, used plasma filaments that were produced by his Plasma Focus device,[1] to produce some fusion reactions that emitted high-energy neutrons, but he did not achieve breakeven conditions.

Bostick noted that a vortex filament can, under certain conditions, bend its axis around and attach the two ends together, forming a *vortex ring*. The advantage of a vortex ring is that the overall flow of plasma is circular, so there is much less drain of plasma out of its magnetic confinement.

Daniel Wells, a student of Bostick, created a machine which could produce vortex rings of plasma directly, with a *conical theta pinch coil* at the end of a cylindrical device. The theta pinch coil is related to the solenoid coil discussed in previous parts of this article.

1. Winston Bostick, "The Pinch Effect Revisited," *International Journal of Fusion Energy*, Vol. 1, No. 1, March 1977.

Wells built his first plasma fusion machine, the TRISOPS I, at the Princeton Plasma Physics Laboratory in the early 1960s. The device was not a doughnut-shaped torus, but rather a long cylinder. Theta pinch coils could generate plasma vortex rings at each end of the cylinder, somewhat like smoke rings, which accelerated to collide in the center area of the cylinder, with high plasma temperature and density. Subsequent experimental machines with this physical geometry are sometimes called "colliding beam" devices.

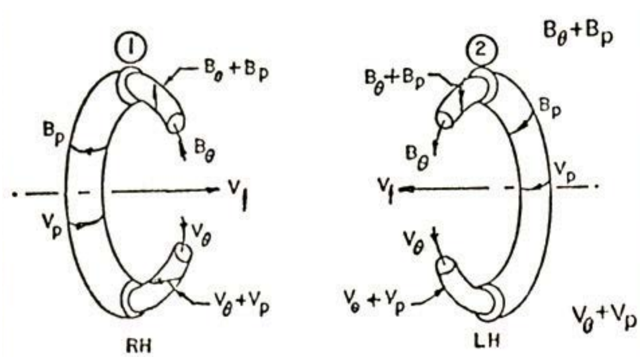
This plasma vortex ring itself does form a doughnut shape, with the magnetic field lines and electric currents circulating around within the doughnut. The doughnut shape is called a plasma *toroid*, to distinguish it from a torus, which is just its geometric surface. Circulation the long way around the toroid is called toroidal, and circulation the short way around through the hole in the doughnut is called poloidal (**Figure 1**).

Daniel Wells joined Bostick on the Scientific Advisory Board of the Fusion Energy Foundation (FEF), and he was on the Initiating Editorial Board of the *International Journal of Fusion Energy (IJFE)*. Both the FEF and *IJFE* were started by Lyndon LaRouche, to promote science and move the worldwide economy to a new energy source, fusion energy.

Plasma Spirals Around a Magnetic Field

Before giving an overview of a plasma vortex ring (**Figure 2**), we will review the formation of a vortex

FIGURE 2
Two Plasma Toroid Rings

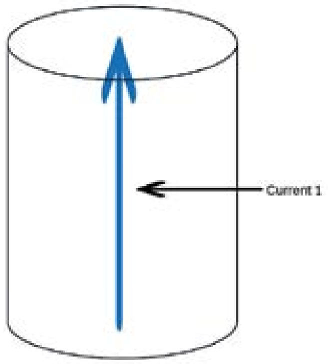


A plasma toroid consists of spirals of electric current and plasma around a central axis, similar to the vortex filament, but with the toroidal axis curved around to form a closed loop—a vortex ring. One filament is co-rotating, and the other is contra-rotating. The filaments here have parts cut away, to show the inner layers. (Source: Wells, Daniel, "Production of Fusion Energy by Vortex Structure Compression," International Journal of Fusion Energy, *Winter 1978, Vol. 1, Nos. 3-4, p. 7.)*

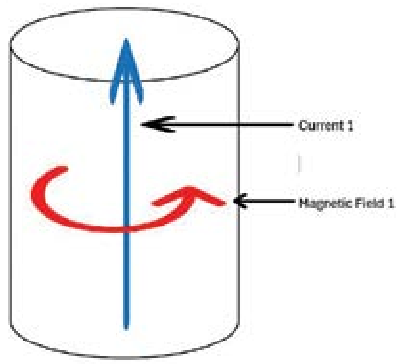
FIGURE 3

Formation of Co-Rotational and Contra-Rotational Plasma Vortex Rings

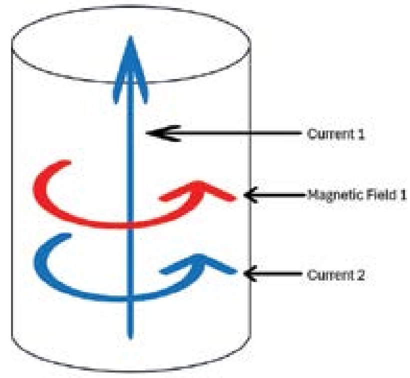
All figures by the author, Dr. Ned Rosinsky.



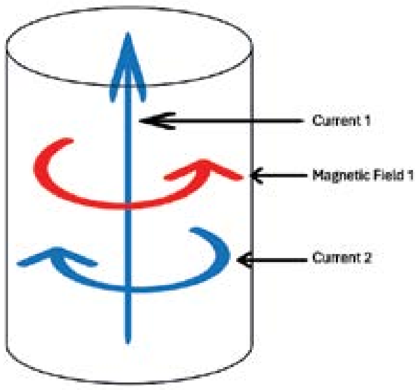
3a. *The first step in forming a vortex filament is the initial Current 1.*



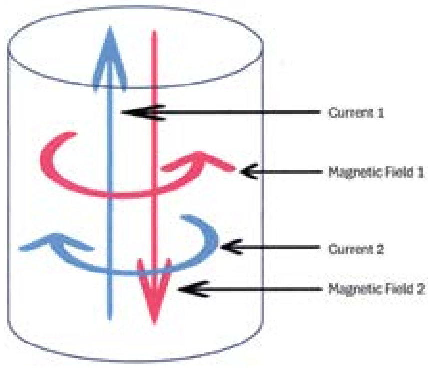
3b. *Current 1 induces rotating Magnetic Field 1, as indicated by the right-hand current rule.*



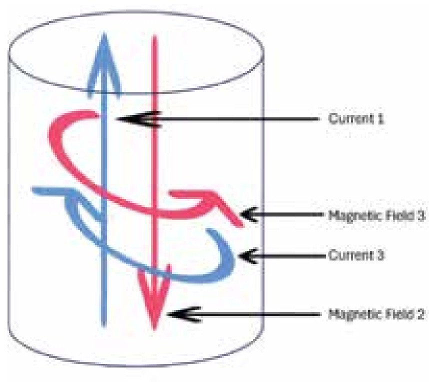
3c. *Magnetic Field 1 recruits particles to form Current 2, rotating in the clockwise direction. This is the pathway that will produce a co-rotational vortex filament.*



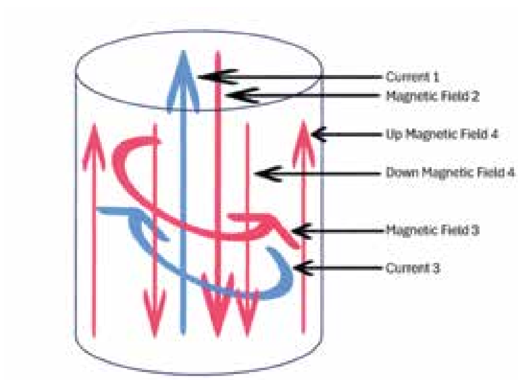
3d. *Magnetic Field 1 can also recruit a Current 2 directed counter-clockwise. This is the current pathway that will produce a contra-rotational vortex filament.*



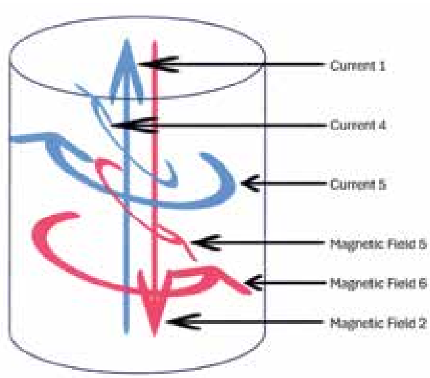
3e. *Current 2 creates a downward Magnetic Field 2, antiparallel to Current 1.*



3f. *The vectors of Magnetic Field 1 and Magnetic Field 2 add to create Magnetic Field 3, spiraling downward. Magnetic Field 3 recruits particles to create Current 3. Current 3 is pointed up, due to the surrounding electrical field being up, so it is anti-parallel to Magnetic Field 3.*



3g. *Current 3 produces Up Magnetic Field 4 and Down Magnetic Field 4, which are parts of the same solenoidal field. Current 3 acts as a solenoidal coil, and creates Down Magnetic Field 4 within Current 3, and Up Magnetic Field 4 outside Current 3. See Part I, Figure 3, for the form of a solenoidal magnetic field.*

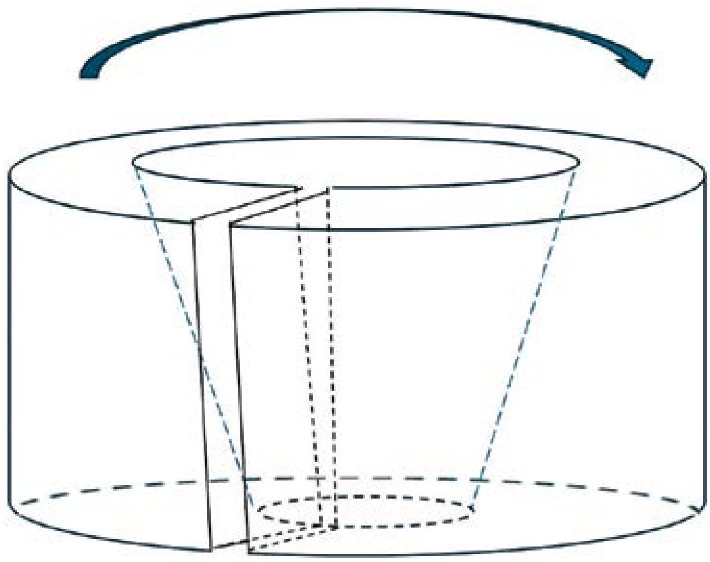


3h. *Down Magnetic Field 4 adds to Magnetic Field 3 to produce Magnetic Field 5. Up Magnetic Field 4 adds to Magnetic Field 3 to produce Magnetic Field 6, which is still downward but less so. Magnetic Field 5 recruits Current 4, and Magnetic Field 6 recruits Current 5.*

filament, as presented in Part II of this article.

When a magnetic field, in a plasma, recruits charged particles (negatively charged electrons and positively charged ions) to form an electric current parallel to its field lines, the charged plasma particles start to spiral in two ways: around the field lines in a narrow spiral whose axis is parallel to the field lines; and around the plasma filament's own axis in a larger spiral. The narrow spiral involves a constant change in the direction of the particles as they move around the field lines—a radial acceleration (Part I, Figures 8 and 9). This radial acceleration can cause photons to be emitted in opposition to the acceleration—that is, away from the magnetic field line. This radiation decreases the energy of motion of the plasma particles, which decreases the radius of their spiral motion; that spiral comes closer and closer to the magnetic field line.

FIGURE 4
A Solid Conical Theta Pinch Coil, with Current Flow Indicated



In addition to the current and magnetic field vectors, the plasma flow, which is the movement of all the particles in the filament, has its own velocity vector and rotational vector. The total plasma velocity vector is usually in the same direction as the current vector. The rotational vector around the axis is like the rotation of a metal screw; its direction is positive for clockwise rotation and negative for counter-clockwise rotation.

There are two types of vortex filaments: co-rotational, those with currents parallel to the magnetic field lines; and contra-rotational, those with currents anti-parallel to the magnetic field lines. Both are stable, with no "Lorentz force" between the currents and field lines. Just as a vortex filament can be changed to a vortex ring by curving the central axis of the filament around, so that the two ends of the filaments come together, a co-rotational vortex filament can produce a co-rotational vortex ring, and a contra-rotational vortex filament can produce a contra-rotational vortex ring (**Figures 3a-h**). The importance of the two types of vortex rings is that one of each was required to form a magnetic bottle in Wells' TRISOPS machine.

Wells used the above-cited conical theta pinch coil (**Figure 4**) to form the solenoidal field that creates the vortex rings. Because this coil uses high-strength currents and magnetic fields, it is not made from windings of wire like a usual solenoid coil, but is a solid piece of metal, in a cylinder shape like a thread spool, so it will not break under the stress of operation. The solid metal cylinder has a cone-shaped volume removed, creating a conical space which extends from one end of the cylinder to the other. There is also a slit cut through the cylinder, from the cylinder's outside surface to the outside of the conical space within it (see, again, **Figure 4**).

A *theta pinch coil,* of which the conical theta pinch coil is one type, is usually a single-turn coil used in plasma physics to create a strong magnetic field. Similar to the action of a solenoid coil, it causes a magnetic field within the coil (see Part I, Figure 3). This magnetic field then causes nearby plasma to cycle in a cylindrical shape around the field. Their interaction causes the plasma cylinder to "pinch"—to narrow, and become denser and hotter.

The theta pinch was the basis for some of the early tokamak fusion test reactors produced in the 1950s, in which a magnetic field circled around in a toroid-shaped fusion chamber, concentrating the plasma. There are external field coils in the tokamak that produce a toroidal magnetic field and a poloidal magnetic field, which add together in the plasma, resulting in a spiral magnetic field. This spiral magnetic field is nearly parallel to the spiraling plasma flow, resulting in a stable configuration. Besides increasing plasma density and temperature, the pinch would help keep the plasma away from the walls of the confining toroid, so the wall material would not be vaporized and contaminate the plasma.

Operation of the TRISOPS

In Daniel Wells' TRISOPS I machine, the one-turn conical theta pinch coil was placed into one end of a long cylindrical Pyrex chamber—also called a drift tube—with the wide end of the cone space facing toward the other end of the chamber (**Figure 5**). Wires from the positive and negative terminals of a capacitor bank (for electric current) were connected to the two faces of the slit in the one-turn cylinder (see, again, **Figure 4**). Thus, the current flowed into the cylinder and made one turn around its axis before leaving the cylinder. This current flow created a solenoidal magnetic field directed along the coil's central axis (see also Part I, Figure 5).

This magnetic field then created a rotating current within the cone space, like the secondary coil in a transformer. (The first rotating current was clockwise; the second was counter-clockwise.)

Wells measured the electrical field in the conical space. He found that there was an accumulation of positive charge centrally around the cone's main axis, and an accumulation of negative charge near the peripheral surface of the cone, creating an electrical field starting from the axis and extending in all directions radially to the peripheral area. This was due to a Lorentz force interaction of the main magnetic field produced by the theta pinch coil with the rotating current in the cone space.

As indicated, the magnetic field is strongest at the narrow part of the cone space, and weakest at the wide end. This change in magnetic field strength is termed a magnetic field gradient, and it can exert a force on a moving charge or a charged particle. The direction of the force will be perpendicular to the motion of the charge, and to the direction of the field gradient. Since in the TRISOPS, the gradient was fanning out in the cone, and the charges were cycling around the axis of the cone, the magnetic force was slanted toward the cone's axis, and also out of the cone.

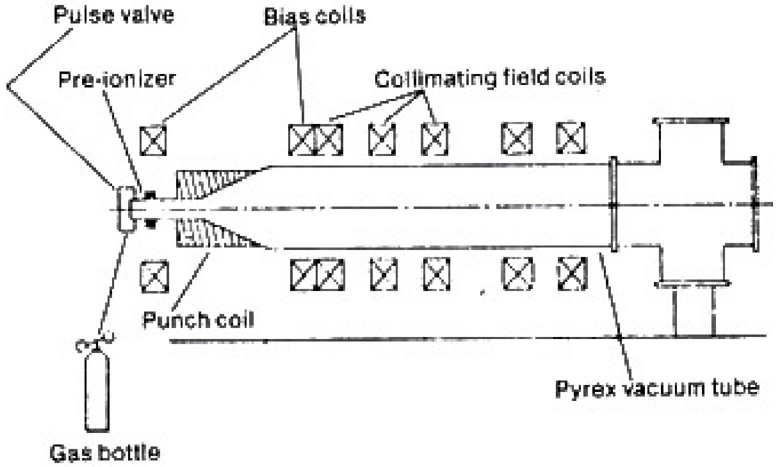
Thus, the magnetic force propelled the cycling plasma out of the cone.

Propelling the cycling ring of current out of the cone space caused a poloidal rotation on the ring, similar to the spreading flow on the front face of a blown cigarette smoke ring, which curls around in all directions and comes together towards the back face. This rotation, combined with the charge separation into positive and negative regions, generated a poloidal current (the short way around the ring). The poloidal current then generated a toroidal magnetic field (circling the ring the long way) in the circulating current.

There were additional solenoidal coils around the cylindrical Pyrex chamber of the TRISOPS, that created a magnetic field of 4,000 gauss through the chamber, parallel to the field produced by the conical theta pinch coil.

The machine began operation with a pulse of gas moving through a "pre-ionizer" coil to heat it up to plasma temperature. The plasma was then pumped into the conical theta pinch coil, and a current then activated into the coil. This cycling current created a magnetic field in the cone space directed along the axis and pointing toward the wide end of the space. The magnetic field created a rotating current. If the current rotated clockwise, the subsequent steps produced a vortex ring which is co-rotational. If the current rotated counter-clockwise, the resulting vortex ring was counter-rotational.

FIGURE 5
TRISOPS I



A side-view cross-section of the first TRISOPS machine. The conical theta pinch is located at the left of the long plasma chamber. A pulse valve allows gas into the pre-ionizer which heats the gas to plasma temperature. The gas is then pumped into the theta pinch coil (cross-hatched), and a surge of current in the coil occurs, forming a magnetic field in the coil directed to the right. The plasma in the coil space forms a rotating plasma ring due to the magnetic field in the coil space. The magnetic field gradient in the theta pinch coil propels the ring out of the coil area into the long plasma chamber.

Source: Daniel Wells , *IJFE*, Vol. I, Nos. 3-4, p. 24.

There were two modes of operation of the conical pinch coil's electric current, dynamic and static. The dynamic mode used an automatic current cutoff, called a crowbar circuit, which stops the current if the current goes over a certain amount. The static mode had no crowbar circuit.

In the first machine built by Wells, TRISOPS I, the current was driven by a maximum operating voltage of 25 kV (25,000 volts). The current was applied in the form of rapid pulses, with each quarter cycle around the conical theta pinch lasting 25 microseconds. Wells found that the use of the static mode created vortex rings—several rings in sequence with each pulse.

On further evaluation, he found that in the static mode, the conical theta pinch coil developed a resonance with the solenoid coil surrounding the cylinder, in the form of a rippling current. This rippling effect resulted in the current in the theta pinch coil changing direction, back and forth. This change in theta pinch coil current caused the magnetic field within it to change direction, pointing either toward the wide end of the conical pinch coil or toward the narrow end, back and forth. And this oscillating magnetic field then caused the circulating electrical current within the theta pinch coil to reverse direction, going back and forth from clockwise to counterclockwise. When the current was clockwise, it would rapidly produce a co-rotational ring; when it was counterclockwise, it would produce a counter-rotational ring. These rings would be propelled out of the theta pinch in an alternating series.

Rippling of currents is usually considered to be noise, and is usually removed from current by electronic filters. Here though, that rippling is essential to the ability of the machine to make plasma vortex rings.

The vortex co-rotational rings carried a magnetic field pointing in the direction of the ring travel through the chamber, while contra-rotating rings carried a magnetic field opposite to the direction of travel. Rings with the magnetic field pointing in the same direction as the background magnetic field in the chamber were stable, but those with magnetic fields opposite the background field disintegrated. This resulted in the series of stable rings from one conical theta pinch being all co-rotational, and coalescing into one larger co-rotational ring; while the stable series from the other conical theta pinch were all contra-rotational, and coalesced into one larger contra-rotational ring. These two final larger rings, one co-rotational and the other contra-rotational, would then meet at the center of the machine and form a stability for a short time, potentially long enough to be heated to fusion temperature at that point by a sudden increase in the surrounding background field.

Pinch Coil 'Blows' Stable Plasma 'Smoke Rings'

Continuing with TRISOPS I, the conical theta pinch coil was located at one end of a 1.5-meter Pyrex cylindrical vacuum tube. The theta pinch coil had a 10-microsecond (ten millionths of a second) cycle time, and a maximum operating voltage of 25,000 volts. Solenoidal coils were placed around the drift tube, creating an external magnetic field of 4,000 gauss. Plasma was introduced into a pre-ionizer to heat it, and the plasma was then pulsed into the conical theta pinch coil.

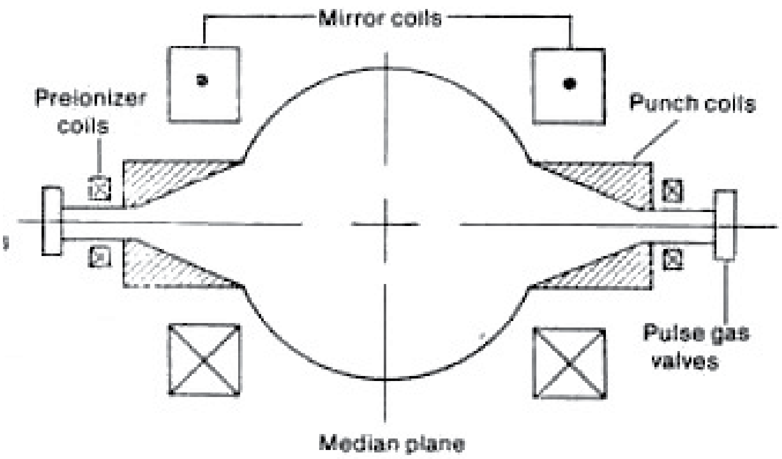
Repeated pulses of plasma into the coil, with repeated activation of the coil, produced a series of rings that were ejected from the coil into the vacuum drift tube. A vortex ring was produced at each half-cycle of the conical theta pinch. The plasma density of the first ring coming out of the pinch was a very dense 10^{15} (million billion) particles per cubic centimeter. The velocity of the rings ejected by the pinch was $7.5x10^{6}$ centimeters per second (176,000 miles per hour). The rings were measured with microwaves for density and mass, photographs, and electric and magnetic probes. Several weaker rings were produced after the first strong ring by the rapid series of pulses. The rings added together to form a long structure with a well-formed head and a long trailing tail.

A magnetic probe sensor showed that the plasma rings each had a trapped poloidal magnetic field of 1,000 gauss, and a trapped toroidal magnetic field of 200 gauss. These trapped magnetic fields were the first evidence that the rings were vortex structures with force-free parallel or anti-parallel magnetic fields and currents.

The rings moving through the guide tube remained centered and in stable pathways. Wells did a study of the forces involved, which included a force of the guiding magnetic field on the current in the ring, pulling it towards its own axis (a "Lorentz Force"); and a mass effect of the plasma pulling the ring outwards in all directions (a "Magnus Force").

It should be kept in mind that the Magnus Force is not an electromagnetic force. This mass effect is similar to the sideways push of air on a spinning tennis ball, causing the path to curve. The poloidal spin of a vortex filament likewise pulls it sideways at each

FIGURE 6
TRISOPS II



Source: Winston Bostick, *IJFE*, Vol. 1, Nos. 3-4, p. 26.

point, expanding the ring. However, the Lorentz and Magnus forces, in opposite directions, tend to stabilize the torus.

There is a term referring to a combination of Lorentz forces and hydrodynamic forces, which is "magnetohydrodynamics," abbreviated MHD. Wells had extensive experience in designing airplane wings prior to his work with fusion plasmas, so he was prepared to work with MHD, particularly in the area of organized turbulence.

The Vortex Rings Collide

TRISOPS II was built at Princeton Plasma Physics Laboratory by Wells in 1965 (**Figure 6**). After construction, the machine was transferred to the University of Miami, where Wells had a faculty position. This machine was built to study the interaction between two vortex rings when they are fired at each other from opposite ends of the machine.

A conical theta pinch coil was located at each end of the machine, facing towards the center. The central part of the machine was widened into a spherical shape 18 inches wide. A background magnetic field was necessary for stable vortex formation. The several plasma rings generated at each end combined into one larger ring, and the two larger rings met in the middle of the chamber. The rings showed some stability only if one was co-rotational and the other counter-rotational. The motion of the combined rings increased as they moved toward the center, and the diameters decreased. At the point of impact, they remained stable for 200 microseconds. Then the rings increased in size and started moving back towards the source ends of the machine, indicating that their magnetic fields had reversed.

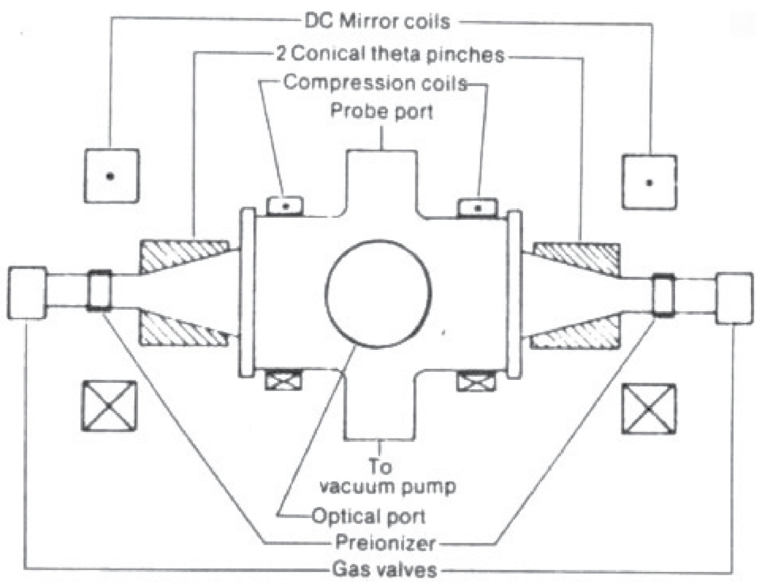
Magnetic probes indicated that the internal magnetic fields of the rings had reversed, and temperature measurements showed 350 eV, which is 4 million degrees K.

TRISOPS III was built in the early 1970s to investigate heating the pair of rings after they come together (**Figure 7**). It created a plasma from deuterium gas by sending it through a pre-ionizer at either end of the cylinder, and then passing the plasma through the theta pinch coils. These pinch coils were powered by a 1 micro-farad, 50 kilovolt capacitor.

At the center of the machine, the plasma rings were compressed and their currents amplified by secondary coils located outside the plasma chamber. The current in the plasma rings reached 120,000 amps. The temperature of the ions reached 170 eV, which is nearly 2 million degrees K. The rings remained stable for 20 microseconds.

The results of this testing showed that plasmas

FIGURE 7
TRISOPS III



Source: Winston Bostick, *IJFE*, Vol. 1, Nos. 3-4, p. 30.

with fusion potential can be created with stable vortex structures.

TRISOPS IV was built in the late 1970s to test the use of a plasma chamber just 3 inches wide, which would allow the solenoidal coils around the chamber to be closer to the plasma rings inside it, to allow more compression and heating of the rings. When the rings collided, temperatures up to 5 keV were obtained (58 million degrees K), with an ion density of $2x10^{17}$ ions per cubic centimeter. The production of neutrons was measured and a flow of 1 million neutrons per pulse was obtained, with strong evidence that these neutrons were due to the fusion of deuterium.

TRISOPS V was planned, with an increase in the background magnetic field to 100,000 gauss, and it included a wider compression chamber to allow for increased ring size. The target goal was to hold the rings stable during heating for 100 microseconds. This would bring the machine to the threshold of the power plant stage. However, the program at University of Miami lost Federal funding at that point.

In 1981 Wells was granted a patent for attaching three TRISOPS units, side by side in a parallel configuration. Each of the units used separate conical theta pinch coils. The coils produce plasma vortex rings, one at each end of each of the units. The rings come together in the middle of the vacuum chamber and collide, which stabilizes the rings. In 1982 Wells was granted a patent for expansion of the 1981 patent to include seven TRISOPS units in one compact reactor.

The Solar System

In 1985, the Fusion Energy Foundation (FEF) agreed to continue Wells' funding to develop the TRISOPS. However, in 1987 the FEF itself was shut down by the Federal Government.

Wells died in 2001, and his effect on fusion research was summarized by a close collaborator in a remembrance, as follows:

> Wells' theory of minimum-energy configurations for magnetic confinement of hot, thermonuclear plasmas became the basis of fusion experiments involving spheromaks, compact tori, and reversed-field pinches throughout the world.[2]

During a meeting with LaRouche and other scientists in 1986, LaRouche prompted Wells to do a study of the Solar System considering the spacing of the planets. Wells used an approach based on least action, and found evidence indicating that the Solar System may have developed from a large pancake-shaped disk of plasma, by electromagnetic resonance, resulting in a circular flow of plasma rings in the disk.

The spacing of planets on this disk could have been related to the pattern of vibrations on a round surface, similar to the pattern of resonance on a drum-head. There are standard modeling tools for describing this kind of resonance. Wells found excellent agreement of the orbital data with the models based on least action.[3] LaRouche wrote a commentary on the Wells Solar System model, stressing that the model demonstrates underlying physical principles of self-development present on the very large scale and the very small scale.[4]

The Wells model implied that the Earth was created from a plasma ring as part of this system of concentric rings. Wells was able to account accurately for the spacing of all nine planets, the asteroid belt, and the Earth's Moon as a possible captured planet between the Earth and Mars.[5]

Wells thought that this disk-shaped plasma may have resulted from a cylinder of plasma collapsing in the longitudinal direction as its energy decreased. The cylinder of plasma itself may have come from an astronomical event such as a supernova, throwing jets of plasma shaped like cones; so the primary initial shape could have been a cone.

Wells followed up his interest in the Solar System by publishing several other articles, including attempts to unify the forces of gravity and electromagnetism, by using geometries from his work with plasmas.

In the final part of this article, we will likewise broaden our outlook by reviewing fusion machines that are currently being developed and that are close to achieving breakeven, such as a field-reversed pinch.

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2. Charles Stevens, "An Appreciation of the Work of Fusion Scientist Daniel Wells," *21st Century Science & Technology Magazine*, Fall, 2001, pp. 12-13.

3. Daniel R. Wells. "Was the Titius-Bode Series Dictated by the Minimum Energy States of the Generic Solar Plasma?" *IEEE Transactions on Plasma Science*, Vol. 18, February 1990, pp. 73-76.

4. Lyndon LaRouche, "Concerning the Coming Report on 'Keplerian Orbits' in Local Plasma and Related Events," *Executive Intelligence Review*, Vol. 48, No. 22, May 28, 1986, pp. 34-38.

5. Daniel R. Wells and M. Bourouis, "Quantization Effects in the Plasma Universe," *IEEE Transactions on Plasma Science*, Vol. 27, Issue 2, April 1989, pp. 270-281.