LPP Focus Fusion Report

December 23, 2014

HAPPY HOLIDAYS & HAPPY NEW YEAR!

Summary:

- **Tungsten Cathode Nears Completion**
- **IEEE Spectrum Covers Alternative Fusion, Including Focus Fusion**
- **LPPF Releases Processed Data to Public**
- **FF-1 Upgrade Continues, Preparations Begun for pB11 Operation**

Tungsten Cathode Nears Completion after Long Delays

The long-awaited tungsten cathode is finally nearing completion in a Chinese factory. According to the latest reports by California-based Tungsten Heavy Powder(THP), which is performing the work in China, machining will be complete within a few weeks and delivery to LPPFusion should occur by mid-February. The 99.95% pure tungsten piece has been in the machining process for nearly two months. Because pure tungsten is as brittle as ceramic and liable to cracking, the part must be removed from machining frequently and heat-treated to relieve internal stress.

“We know that it seems the vital electrode is always two months in the future, sort of like fusion but with a shorter time line,” comments LPPFusion President and Chief Scientist Eric J. Lerner, “but this time we know the final stages of machining are actually underway.” (see Figure 1)

Fig 1- Tungsten cathode undergoing machining in China on Nov 19*, two weeks into the two-month long process. Note the 16 vanes emerging from the tungsten blank. The inward-facing surfaces of the vanes will carry the current once the finished piece in in FF-1.*

The long wait for the tungsten cathode comes from the inherent technical difficulty of the part, which is pressing close to the limits of present day tungsten technology. Since tungsten melts at a higher temperature than any other material, it can't be poured and cast. Instead tungsten powder is pressed or sintered together at high pressure and temperatures to form a solid piece. This process makes it difficult to form thick pieces and the monolith tungsten cathode is over 15 cm tall. No factory outside of China is now equipped to make such a thick pure-tungsten piece.

This technical difficulty has led to long delays. While LPPFusion decided to make the monolithic tungsten cathode in May 2013, the initial supplier, also in China, fell through when it increased the estimated cost abruptly ten-fold to over $140,000. When no other supplier was willing to complete the part, LPPFusion contracted with THP to produce a cone-shaped blank and with a NJ-based company to machine the final shape, a process that was supposed to be completed by June, 2014. Unfortunately the NJ company first decided that a third firm was needed for initial machining of the part (see Cathode Gets More Machining) and then backed out of the deal entirely, citing too much technical risk.

Finally THP agreed to make the part start-to-finish and, after getting corrections on an aluminum model (see Tungsten Anode Goes Into FF-1; Aluminum Cathode Model Is Checked), began machining a new blank at the beginning of November. The entire machining process will take about two months.

Given the extreme difficult of making the tungsten cathode, why does LPPFusion not go directly to the final beryllium electrodes? The answer is that tungsten, with its extreme resistance to heat, is the lowest risk material for the next step of our experiment. We need to eliminate evaporation of the electrode and the resulting impurities to get a jump in the density of our plasmoid, and in the resulting fusion energy output or yield. We have firm experimental evidence that tungsten does not erode under the condition FF-1 is currently running. While we have developed and published well-founded theories of how pre-ionization can stop erosion of much less heat-resistant material like beryllium, we still need to test those theories experimentally. That we can do safely with tungsten, with risking damage to the electrodes or disappointing fusion results. In this way we will confirm or refine the theories and technique, paving the way for the beryllium electrodes.

Those beryllium electrodes will be ready when we need them. We expect to order them in January, with delivery in the first half of 2015.

IEEE Spectrum Covers Alternative Fusion, Including Focus Fusion

One of the leading technical journals in the world, *IEEE Spectrum*, has reported in its December, 2014 print edition on alternative routes to fusion energy.

LPPF's work is mentioned in the first few paragraphs of the story and described briefly as one of five leading fusion alternatives, along with University of Washington's Dynamak, which is featured, and the efforts of Lockheed-Martin, Helion Corporation, and General Fusion. *IEEE Spectrum* is read by 430,000 engineers and physicists around the world, so the article gives good visibility to LPPF's work among the audience with the most interest in it.

Spectrum has been covering alternative fusion for a long time. In July, they featured LPPF's Indiegogo campaign in an energy blog online. Indeed, back in 1980, *Spectrum* published an article by Eric Lerner, then a Contributing Editor of *Spectrum* and now LPPFusion President and Chief Scientist, on fusion, including alternatives like the dense plasma focus. It was during the writing of that that Lerner started the theoretical research that later led to the current focus fusion project.

In the same December, 2014 issue of *Spectrum*, engineers Ross Koningstein and David Fork discuss some of the obstacles to achieving clean energy in the near future and shed light on the failure of Google's RE<C initiative to achieve its goal of renewable energy that is cheaper than coal. The authors, who worked on the RE<C project and are still employed by Google, point out that the Google initiative, which ran from 2007-2011, relied on incremental improvements on proven existing technologies, such as wind, solar and geothermal. Instead, what was needed was to invest in "truly disruptive technology". They gave as an example a fusion technology that could produce electricity directly from high-energy charged particles instead of from converting heat into steam. Of course, only aneutronic fuels, such as the hydrogen-boron fuel that Focus Fusion will use, are capable of such direct conversion.

In 2007 Lerner was invited to speak at a Google Tech Talks session, describing just such a disruptive technology—the one which we are continuing to develop. This talk, posted online, gave extremely important publicity to our project. However, the RE<C project, then just getting started, declined to fund Focus Fusion or indeed any other fusion project. Koningstein and Fork's article shows the realization that, in retrospect, this was a mistake. Now, the authors say RE<C "didn't go far enough, and that truly disruptive technologies are what our planet needs." They urge that 10% of R and D money be devoted to "strange new ideas that have the potential to be truly disruptive."

LPPF Releases Processed Data to Researchers and the Public

Developer of the LPP Java FFusion program - LPP Electrical Engineer Fred Van Roessel

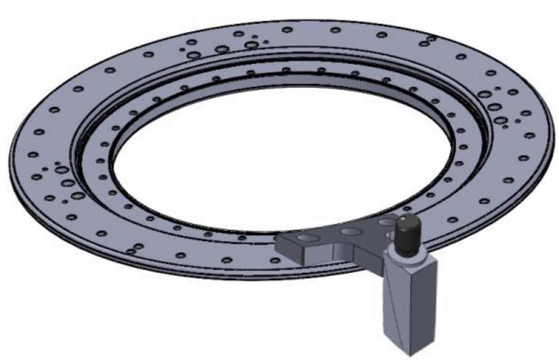
LPPFusion, Inc. has made available on our website the data in our Processed Data Base to all researchers, both professional and amateur. This data provides the key observations for each shot from the start of operation of Focus Fusion-1 in 2009 through the end of 2013 for four instruments: the Main Rogowski coil (MRC), High Voltage Probe (HVP), the Near Time of Flight (NTF) and Far Time of Flight (FTF) detectors. This gives data on the current and voltage produced during a shot and the neutrons and x-rays emitted. We are making this data publically available in the expectation that other researchers will be able to use the data to provide new insights into the functioning of the Dense Plasma Focus device and advance the field generally.

In contrast to the data base of raw data made public last year, this data has been processed by our own Java Fusion program into more useful form. The program, developed by LPP Electrical Engineer Fred van Roessel, measures such key parameters as the peak current and peak voltage of each shot, and identifies and measures the timing, width and height of each neutron and x-ray peak. It automatically aligns the data in the NTF and FTF, showing which peaks correspond in the two instruments. This is work that almost any researcher would need to do before further analyzing the data, so we are here eliminating a lot of effort and duplication of work. We ask that all those downloading this data share their analyses with LPP, publish their results and of course cite our work accordingly.

FF-1 Upgrade Continues, Preparations Begun for pB11 Operation

While FF-1 can't fire until it gets the new tungsten cathode, the lab has not been sitting idle. The LPPF team has undertaken significant upgrades to the device, and started work on further ones. Other than a complete disassembly, cleaning and re-assembly of the vacuum chamber and drift tube to eliminate all sources of impurities, the team has improved assembly techniques to achieve greater symmetry in the device and greater protection for the new cathode itself.

One key improvement is in the process of centering the cathode, the outer electrode, on the anode, the inner electrode. Since there is a tight fit between the two electrodes and the insulator sandwiched between them, any slight asymmetry can affect the amount of plasma trapped in the small space between the parts, and thus potentially the speed of the rundown and the symmetry of the pinch. In the past, centering was done by shimming the part with plastic shims. Now, however, precision micrometer adjustment devices will be mounted on four sides of the steel plate that is attached to the monolithic tungsten cathode (see drawing). The micrometer will allow centering of the cathode on the anode to a precision of 25 microns or less and make the process far faster than the shimming. The design work was performed by Consulting Engineers Jonathan Klabacha and Tony Ellis and our new volunteer engineer, Marc-Antoine Legault.



Drawing of the precision micrometer adjustment device and cathode connection plate.

We are also preparing for a further stage of our experiment, when we switch from using deuterium as a fuel to our final aneutronic fuel, hydrogen-boron or pB11. We have checked our 250-gm supply of decaborane—the compound of hydrogen and boron we intend to use and Chief Research Officer Dr. Hamid R. Yousefi has selected the safety equipment we need, such as glove boxes to handle the material, whose vapor is somewhat noxious. We are in the process of designing and purchasing the equipment needed to heat the device to approximately 120 C, needed to create the vapor pressure to fill the vacuum chamber. While it is still months before we are ready to run with decaborane, we will be ready to make the transition with as few delays as possible.

In addition, we are undertaking a major upgrade of our computers and data processing, which we will report on next month.

A Note on Our Name

Readers of these reports may have noticed that we are now referring to our company as LPPFusion, Inc., not Lawrenceville Plasma Physics, Inc, and using the initials LPPF, not LPP. We are in the process of changing our name. While we have not yet changed the legal name of the company, we have wanted to drop the "Lawrenceville" name, which is confusing, since we have not been located in the town of Lawrenceville, NJ for years and our lab is in Middlesex, NJ. In addition our old name did not really say what we are doing, which is developing fusion energy. We expect that it will take time to get everyone, including the media, to start using our new name, so in the interim you can expect to see both names in use. Eventually, we will change the legal name as well. Lawrenceville Plasma Physics, Inc. will be history, but LPPFusion, Inc. will be carrying on—same team, new name.