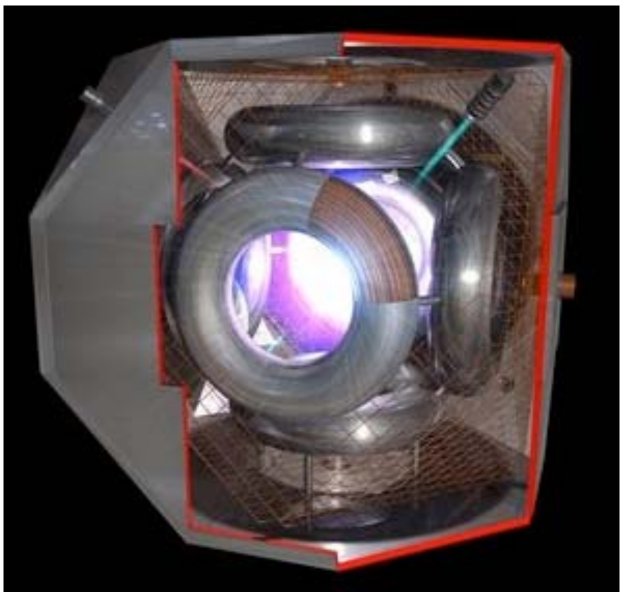
Dr. Richard Nebel Interview

by Sander Olson, Nextbigfuture, May 5, 2009 with subsequent Talk-Polywell Q&A
http://nextbigfuture.com/2009/05/interview-dr-richard-nebel-of.html

EMC2 Fusion is the company that Dr. Richard Nebel is leading to develop IEC/Bussard Fusion. This interview was conducted by Sander Olson as an exclusive for Nextbigfuture.



Question: Could you provide an overview of your nuclear fusion process?

Answer: Our machine is a hybrid machine — part magnetic confinement and part electrostatic. Our approach involves holding plasma together and heating with electrostatic fields. With the parameters that we have put into this device, we have gotten the results that we expected. We are currently using low magnetic fields, and the major issue with this is to what degree it will scale. At this point we don't know the answer to that question.

Question: How is your concept for nuclear fusion different than that of the Government's tokamak project?

Answer: Tokomaks are pure magnetic confinement devices, so the physics on our devices are considerably different than for Tokamaks. The advantage of our system is that high temperatures are not difficult to obtain, but we struggle to get the high densities that magnetic confinement devices do easily. We have disadvantages as well — the things that are difficult for us are easy for them and vice versa. But overall we believe we have a superior concept for several reasons. First, our hybrid system will use p-^{11}B (proton - Boron 11) for fuel, which doesn't produce radioactive material. Second, our system is compact, and could be portable enough to be used on ships. Third, this system is cheap to develop and to run — we don't require enormous development budgets like the tokamak does.

Question: How close are you to creating a fusion machine capable of actual energy generation?

Answer: We are hoping to have a net energy production product within six years. It could take longer, but this definitely won't be a 50 year development project.

Question: You are currently operating on a shoestring budget. How are budgetary limitations hampering your work?

Answer: Unsurprisingly, our biggest constraints relate to funding and schedules. Due to time limitations, we haven't been able to test the device as thoroughly as we'd like, and we couldn't put all of the diagnostics on the machine that we initially wanted. But these constraints compel us to operate efficiently and expediently. My biggest concern at this point is getting things right the first time, which is difficult when doing fundamental research.

Question: When is the earliest that an actual fusion plant based on your concept could be built?

Answer: The project that we hope to have out within the next six years will probably be a demonstration that won't have the attendant secondary equipment necessary for electricity generation. Hopefully the demo will demonstrate everything that is needed to put a full-scale working plant into commercial production. If the concept works we could have a commercial plant operating as early as 2020.

Question: How safe would these fusion plants be, relative to fission reactors? What byproducts would they produce?

Answer: There are no radioactive materials or waste made with this process. The only serious hazard with operation are the high voltages involved that pose a risk to the workers. This is a risk that conventional power plants have as well. These machines shouldn't require containment vessels, like the fission machines have. The only byproduct of our fusion process is helium.

Question: How portable could these devices be made? Could they be used to power ships?

Answer: The navy is funding our work because they are interested in using our fusion technique to power their ships. The minimum size on these machines isn't yet clear, and that will depend on how this scales. Dr. Robert Bussard was very interested in using this fusion technique to power spaceships.

Question: What do you estimate a kilowatt hour from your fusion reactor to cost?

Answer: We are looking at 2-5 cents per kilowatt hour. That should make electricity generation less expensive than any alternative, including coal and nuclear. So if this technology works it will be like a silver bullet, and be fundamentally superior to any competing technology. The issue is whether it works or not.

Question: What fuel sources could your fusion system use?

Answer: Our system uses a proton and the ^{11}B isotope, which is called p-^{11}B. It is easier to run a fusion device on ^{3}He, since it is easier to generate power out of ^{3}He. But there are accessibility issues with ^{3}He, so it is currently extremely expensive. People have argued that we should be mining the moon, since ^{3}He is abundant on the moon. But I believe that p-^{11}B is a superior approach, if we can make it work.

Question: What is your assessment of cold fusion? Will it ever become feasible?

Answer: I don't know if it will ever be feasible or not. What we have seen so far is excess heat production, and we don't know the cause of that. But we should wait and see what the cold fusion proponents accomplish.

Question: Are there any corporations/civilian agencies funding your research?

Answer: There are, but I am not at liberty to discuss that at this point. We currently have multiple funding sources, and certain corporations and private organizations are very interested in this technology. We have had numerous inquiries from various sources, and we tend to be forthright and explain the inherent risks involved. Some corporations are more amenable to funding high-risk projects than others.

Question: If this technology progresses as you hope, how could it affect society?

Answer: If we get super excited about this, than we will lose perspective, and that is deadly for science projects. People who lose perspective tend to start misinterpreting the data to meet their expectations. This technology will either be a world-changing process or a bust. If it works, it will dramatically alter the world within the next two decades. This is a truly disruptive technology, and if successful will result in a safe, cheap, and nearly limitless source of energy.

Discussion

Many of the following questions and answers that follow came from questions and answers on various threads at www.talk-polywell.org that were originally generated by the above interview. While the answers are by Dr. Nebel, the questions are from different individuals.

Question: I think I'd slightly qualify the statement that the p-^{11}B fusion reaction is aneutronic. There are additional reactions possible (e.g, $^{11}B + ^{4}He \rightarrow ^{14}N + n$, $^{11}B + p \rightarrow ^{11}C + n$, etc) that will produce neutrons, even if the Hydrogen and Boron are isotopically pure. If they're not, there are additional reactions possible. Better stated, the p-^{11}B reaction is largely aneutronic.

Answer: We've looked at the side reaction you discuss and it is down 8 orders of magnitude from the p-^{11}B reaction. The reason for this is that the alpha particles are not well confined and leave the system very rapidly. The alpha-^{11}B reaction is the dominant side reaction.

Question: A quick question: what is the effect of deuterium and ^{10}B impurities?

Answer: We haven't looked at impurities yet.

Question: Assuming a Polywell demonstrator works in say 3-10 years, would a developed reactor be able to burn ^{3}He-^{3}He, or does Polywell's performance "max out" with p-^{11}B?

Answer: We looked at ^{3}He-^{3}He and concluded that the fusion reactivity was just too low. (The characteristics of ^{3}He-^{3}He (cross-section, reactivity, Lawson criterion) are at least an order of magnitude below those for p-^{11}B.)

Question: Is that 1-2 years to know if this will work, mean p-^{11}B or does it mean any Polywell?

Answer: I think we have a real shot at p-^{11}B. I think it is possible to beat the Bremstrahlung issue. Nothing is a slam dunk. If the transport doesn't work out, then none of the systems will work. Right now, the transport looks fine. *(The transport issue is how fast energy leaves the system. You need to substantially more energy out in fusion than you inject into the machine. Transport losses determine how much energy you need to inject.)* The question is whether or not it will scale.

Question: What do you anticipate for the ratio of P_{brems} to P_{fusion}?

Answer: The present projected Q values for p-^{11}B vary from about 1.7 to about 12, depending on how the physics breaks. The details of how you do that are surprisingly subtle and coupled, and I'm not going to go into that in this forum. I view this as an "optimistic problem." There are a lot more serious issues that need to be dealt with than this one.

Question: What will the next generation of Polywell machines focus on?

Answer: The major focus for the next generation Polywell is transport. We will be trying to take the machine from "OK" confinement to "good" confinement. Historically, this is a step that has been difficult for fusion machines. The next couple of years are going to be interesting.

Many people are trying to make Polywell arguments using classical collision models. The dominant mechanisms for transferring energy between the ions and the electrons are collective mechanisms, not classical binary collisions. Our experience is that you have to do full-up kinetic simulations if you want to understand these mechanisms and their effects. We've been doing that for the past 1.5 years, and we plan to be doing a lot more simulations over the next 2 years.

Question: How was the WB-6 powered?

Answer: Batteries were used for the coils (high current, low voltage) and capacitors for the coil cases (high voltage, low current). WB-6 power input was ~10 MW.

Question: How do you intend to get the alphas out when their Larmor radius is only a fraction of the machine size?

Answer: The alphas make about 1000 passes before they exit through the cusps. They leave at essentially full energy. The ions also show some magnetic confinement under reactor conditions. Run the numbers. The ion Larmor radii are also smaller than the device size, as are the alpha particles' Larmor radii.

Question: What issues do you anticipate in scaling up a Polywell?

Answer: A few comments on scaling laws. To a certain extent we are in the same boat as everyone else as far as the previous experiments go since Dr. Bussard's health was not good when we started this program and he died before we had a chance to discuss the previous work in any detail. Consequently, we have had to use our own judgement as to what we believe from the earlier experiments and what we think may be questionable. Here's how we look at it:

1. We don't rely on any scaling results from small devices. The reason for this is that these devices tend to be dominated by surface effects (such as outgassing) and it's difficult to control the densities in the machines. This is generally true for most plasma devices, not just Polywells.
2. Densities for devices prior to the WB-7 were surmised by measuring the total light output with a PMT (photomultiplier tube) and assuming that the maximum occurred when $\beta = 1$. We're not convinced that this is reliable. Consequently, we have done density interferometry on the WB-7. We chose this diagnostic for the WB-7 because we knew through previous experience that we could get it operational in a few months (unlike Thomson scattering which by our experience takes more than a man-year of effort and requires a laser which was outside of our budget) and density is always the major issue with electrostatic confinement. This is particularly true for Polywells which should operate in the quasi-neutral limit where Debye lengths are smaller than the device size.
3. As discussed by several people earlier, power output for a constant beta device should scale like B^4R^3. All fusion machines scale this way at constant beta. Input power scales like the losses. This is easy to derive for the wiffleball, and I'll leave that as an "exercise to the reader." This is the benchmark that we compare the data to.
4. As for questions relating to alpha ash, these devices are non-ignited (i.e. very little alpha heating) since the alpha particles leave very quickly through the cusps. If you want to determine if the alphas hit the coils, the relevant parameter is roughly the comparison of the alpha Larmor radius to the width of the confining magnetic field layer. I'll leave that as an "exercise to the reader" as well.

Question: Are losses primarily cross-field or are the losses are dominated by the cusps?

Answer: You compute the loss fraction by:

$$Loss_{fraction} = \sum_{i=1}^{n} \frac{\pi r_i^2}{4\pi R^2} \quad (1)$$

where r_i is the electron gyroradius and R is the coil radius. The summation is a summation over each of the point cusps. If you calculate r_i from one of the coil faces, then there are "effectively" $\sim n = 10$ point cusps (fields are larger in the corners than the faces). The factor that your observed confinement exceeds this model is then lumped together as the cusp recycle factor.

The other model is to look at mirror motion along field lines. For this model you look at loss cones and assume that the electrons effectively scatter every time they pass through the field null region. This model describes the confinement which was observed on the DTI machine in the late 1980s.

I don't know how to predict cross-field diffusion on these devices. The gradient scale lengths of the magnetic fields are smaller than the larmor radii and the electrostatic fields should give rise to large shear flows. On top of that, the geometry is 3-D.

Question: Does the mirror model result in a simple formula? If you have a volume where the field vanishes, how do you handle the infinite mirror ratio?

Answer: The mirror model is a bit of a hand-waving model that I believe Nick Krall came up with. The mirror ratio is calculated from the field where the electron Larmor radius is on the order of the device size. Any smaller field than that will not have adiabatic motion. If particles enter the field null region, it is assumed that they effectively scatter. I believe that Dave Anderson at LLNL did a fair amount of particle tracing calculations for FRMs in the late 1970s, and not surprisingly saw jumps in the adiabatic invariants when moving through field null regions. I presume similar behavior was observed on FRC simulations. Anyway, it's a ballpark model.

My other comment was related to electrons trapped in the wiffleball. Over most of their orbit there is little or no magnetic field (i.e. Larmor radius bigger than the device size) with the electrons turning when they hit the barrier magnetic field. The electron behavior is stochastic since there are no invariants. We don't have any direct measure of the internal magnetic fields, but we do know the density and have a pretty good idea what the electron energy is. High beta discharges should expel the magnetic field. The vacuum fields should be in a mirror regime (as was the DTI device) while the wiffleball fields should transition to better confinement. There is about 3 orders of magnitude difference in the predicted confinement times so it's pretty easy to see which regime the device operates in (unless, of course, the cusp recycle is truly enormous).

Question: You could use Bohm diffusion,

$$D_{Bohm} = \frac{1}{16}\frac{k_B T}{eB} \quad (2)$$

but I wouldn't trust it farther than I could throw it. How do you know "The gradient scale lengths of the magnetic fields are smaller than the larmor radii?" That's hard to measure, and it contradicts Dolan.

Answer: As you suggest, Bohm diffusion is kind of a catchall for any kind of confinement you don't understand. We hope we don't end up there, and so far we're OK.

Publication History

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