the Bell Jar
Vacuum Technique and Related Topics for the Educator & Amateur Investigator

Notes from the Vacuum Shack No. 27 March 2022

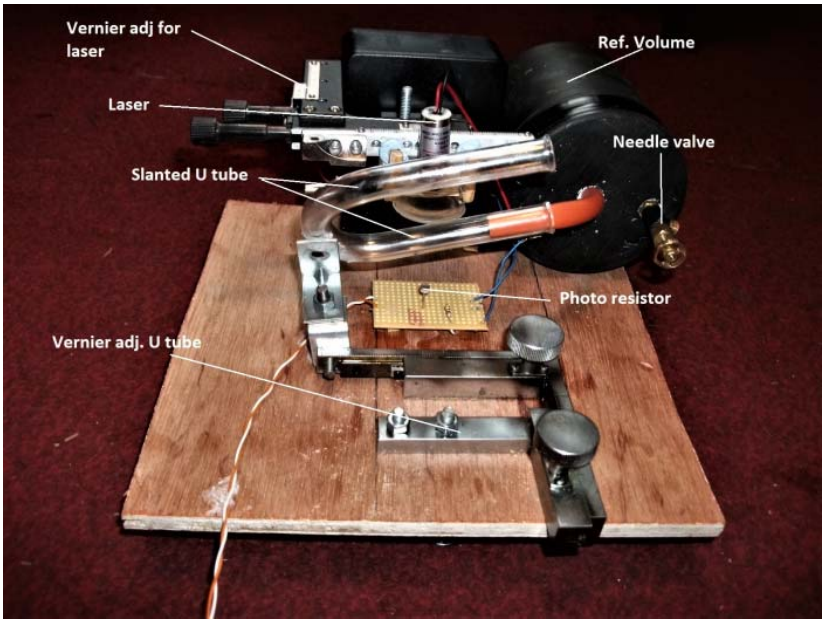
In this issue:

- Update on Albert Noble's liquid column microbarograph
- Quick update on the capillary spark apparatus
- Measure twice, cut once (or not at all)
- Two books on fusion energy and a very different spin-off
- Articles of possible interest in *Vacuum Technology & Coating*

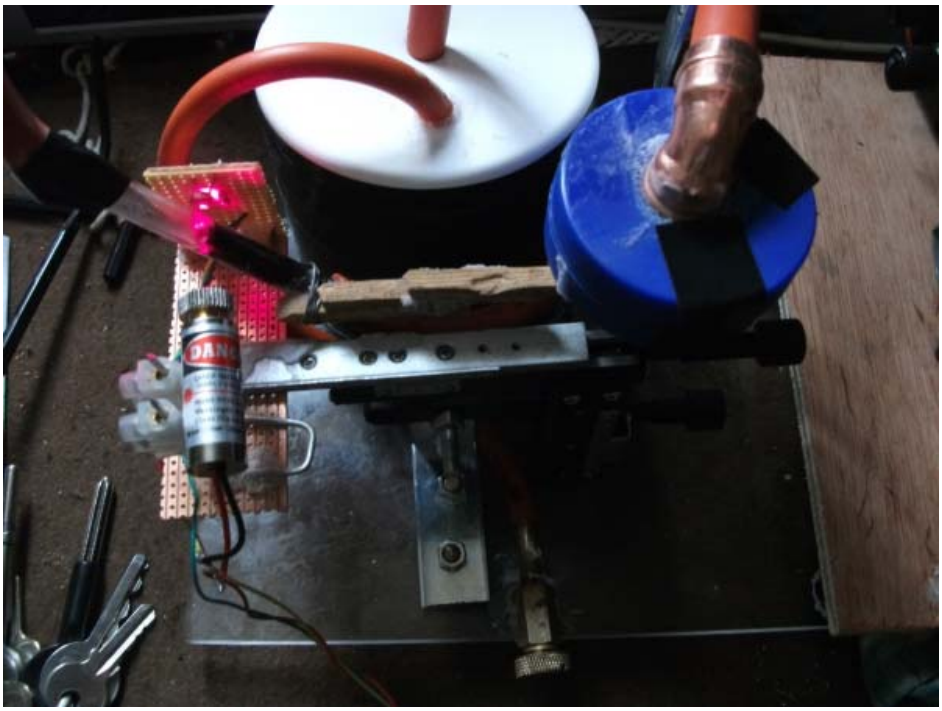
Update on Albert Noble's Liquid Manometer Microbarograph

Albert Noble in the UK has made some good progress with his liquid manometer microbarograph. Here's what has happened since last month.

He slanted the U-tube to provide greater resolution on the side where measurements are taken. He also adjusted the angle of attack for the laser beam to provide greater amplification of the column motion. Verniers have been added for both the laser and U-tube positions for maximum sensitivity. The liquid is an acetate as it's less dense than water thereby also improving sensitivity. Below is an annotated photograph showing this version.



The next step was to provide the manometer with tubes of two different diameters. The side exposed to the reference is a smaller diameter tube and the side exposed to the atmosphere is of a larger diameter. The area ratio is 64:1. Below is a picture of the set up. You can clearly see the laser light glancing off of the liquid surface. The round blue item is the larger liquid container. It has baffles inside to minimize any liquid ripple.



The photograph below shows traces for the original instrument and the one with the modifications. In each he moved a door very slowly to and fro and then faster. The trace voltage range is the same in each case so this shows a direct comparison between the two systems. The horizontal divisions are in fifths of a second. The center trace is that of a seismograph.

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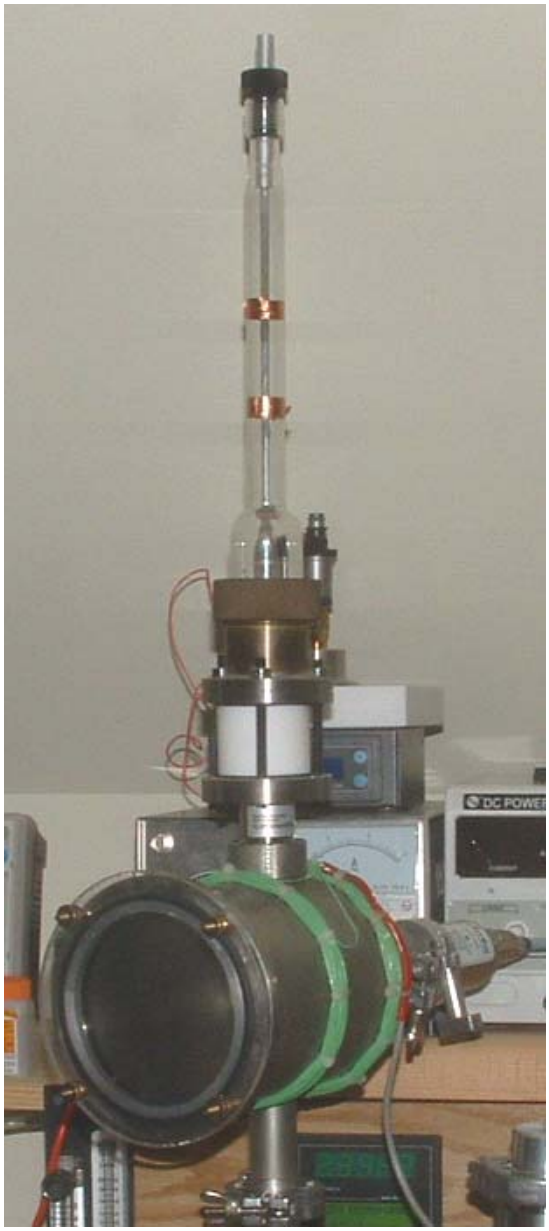
Quick Update on the Capillary Spark Apparatus



I haven't had much time to spend actually doing stuff, but here's where things stand with the capillary spark device.

To the right is a photograph of the entire assembly mounted to my roughing pump port. I'll eventually use it with the turbo pump and a gas leak into the hollow cathode area but it's easier to do basic set up without the turbo in the loop. I used an MKS 925 microPirani for pressure measurements.

Per the literature, the operating pressure in the hollow cathode should be on the order of 1-4 Pa (7.5 to 30 milliTorr). I could pump the assembly to about 24 milliTorr, a bit on the high end of the range. The rate of rise was also fairly steep and linear, indicative of a real leak.

The weak point in the system seems to be the Lexan window on the chamber and its seal to the O-ring. I had to do quite a bit of tightening of the 4 knurled nuts to get the pressure below 100 milliTorr. With the 4 bolts, the window flexes a bit, probably resulting in poorer contact with the O-ring in the in-between areas.

I was going to swap out the chamber with a modified KF 40 reducing tee as I have a nice commercial KF40 view port and it would be tighter than the big chamber with plastic window. That didn't work out (see the next article).

I should have a functional test report next month.

Measure Twice, Cut Once (or Not at All)

Good advice. I should have followed it. In fact, I didn't measure even once. I have (had) a KF40 to KF25 reducing cross (two ports each). I wanted to remove one of the KF25 ports so the tube would mate with the 1" compression adapter used in the capillary spark device. This would provide a smaller and cleaner chamber assembly than the one I am currently using. I assumed that the tube connecting to the KF25 flanges was 1" in outside diameter, like all of the KF25 connecting tubes I've ever seen. After I had cut off the flange and filed the cut nice and smooth, I found out that the tube was more like 1-1/16" in diameter. Oops. I'm sure I'll find a use for the thing at some point. Meanwhile, the search is on for an affordable reducing cross I can hack.

Two Books on Fusion Energy – Still (10-20-30) Years Away

When I was in college, somewhere around 1970, my electrodynamics professor, who was involved in a fusion program, told me that a practical fusion reactor should be possible in 10 years. For a number of years after that I think it stayed at 10 years but then expanded to several decades. On top of that, there's the issue of going from a lab tool to becoming part of the huge energy infrastructure.

A book review in the October 2021 issue of *Physics Today* caught my eye. The review, by Ryan Dahn, was of the recently published *The Star Builders: Nuclear Fusion and the Race to Power the Planet* by Arthur Turrell (Scribner, 2021). I subsequently picked up a copy. This book is very non-technical but provides a good overview of several fusion programs that are ongoing around the world.

The book makes the important point that our current conventional energy sources are running out and, put simply, wind and solar just won't do more than provide a limited amount of energy, perhaps 30% at most.

The programs discussed range from the giant National Ignition Facility (NIF) in the USA to the daunting International Thermonuclear Experimental Reactor (ITER) in France. Also covered are a number of smaller efforts. These include First Light Fusion in the UK which plans to use an electromagnetic rail gun to accelerate a small metal projectile into a target containing deuterium and tritium. By using an enhancement of a known technology (the rail gun) and concentrating on the details of the target, they feel that scale up will have a much faster timeline.

Tokamak Energy, also in the UK, is working with a spherical tokamak configuration which they feel can be scaled quickly and directly into a practical machine. They plan to reach net gain in 2022. Commonwealth Fusion Systems, an MIT spin off, is also pursuing the tokamak approach and is also projecting net gain in 2022. The clock is ticking.

General Fusion in Canada is going to compress a ball of plasma using a symmetrical array of steam driven pistons. TAE Technologies is a well-heeled start up with funding from the likes of Google, Goldman Sachs and the Russian government (quite a combo). They are pursuing the neutron-free hydrogen (proton) – boron reaction.

In 2010 Lockheed Martin said they'd have a prototype power plant in 2015. LPP Fusion in New Jersey is hoping that a dense plasma focus approach will work and will provide "decentralized fusion power." All in all there are a couple dozen startups all promising practical fusion power.

Overall, the book is fairly optimistic. In the author's view, net energy gain from fusion will be achieved soon, and the bigger problem will be quickly deploying fusion power worldwide. The book has no illustrations or photographs which would have been helpful, especially to those that have never seen these devices either in pictures or had the opportunity to visit a facility.

Turrell's book led me to look at *Sun in a Bottle – The Strange History of Fusion and the Science of Wishful Thinking* by Charles Seife (Penguin 2008). The author has written for *Science*

magazine as well as other scientific publications. Because of his association with *Science*, he has an insider's view of a couple of programs. Like the previous book, it is very non-technical but does include a number of photographs and illustrations.

He begins with a history of radiation and atomic reactions, leading up to the hydrogen bomb, the roles of Teller and Oppenheimer and visions of large scale excavations using repurposed nuclear weapons. In his view, huge efforts like ITER and NIF will just show that bigger versions of things that didn't work, will also probably not work. This is not to say they are worthless – they are valuable tools regardless of the outcome.

He spends a good part of the book on the notable failures including the outright fraud perpetrated by Ronald Richter who was supported by Juan Perón. Perón announced in 1951 that Argentina had harnessed the power of the sun. The top secret work was conducted on Huemul Island, located in the middle of a lake. It was eventually shown that no fusion machine existed and the whole thing was pretty much a fabrication. The book also covers cold fusion and the story of the controversy within ONRL and the pending paper in *Science*. More tragic was the story of Rusi Taleyarkhan and bubble fusion which posited that fusion temperatures could be reached via cavitation.

The last part of the book deals with "table top fusion." This includes the Farnsworth fusor. Thiego Olson and Tanhui Li are noted as the first teenagers to construct a working fusor. While not mentioned by name, this section recognizes the work of the group of amateur fusioneers organized by Richard Hull. Other tabletop devices mentioned include those of Todd Ditmire and Seth Putterman.

Toward the end of the book, Seife states with regard to ITER "If, miraculously, no more instabilities crop up that prevent scientists from bottling their plasma, fusion energy will be within reach. Scientists would then build a demonstration fusion power plant that would begin operations in 2035 or 2040. After five decades of broken promises, lies, delusions, and self-deception, it will finally be true. Fusion energy will be thirty years away."

Interestingly, fusion research has touched a seemingly unrelated avenue toward harnessing deep-earth geothermal energy. An MIT spin off, Quaise Energy (https://www.quaise.energy/), is planning to use microwave energy to bore holes in the earth to a depth of 20 km. The temperature at that depth is in excess of 500 °C where steam can be produced to power a conventional power plant. Simply drill a hole next to a coal fired plant and it's back in operation using a virtually limitless power source.

The microwave energy will be provided by a gyrotron, a type of high power microwave device using electron cyclotron resonance. Operating frequencies range up to the hundreds of GHz. Gyrotrons have been used to heat plasmas in fusion research. Their website states: "Our gyrotron-powered drilling platform vaporizes boreholes through rock and provides access to deep geothermal heat without complex downhole equipment. First, we use conventional rotar6y drilling to get to basement rock. Then, we switch to high-power millimeter waves to reach unprecedented depths."

The timeline shows a full-scale drilling rig by 2024, 100 MW of thermal energy from several wells in 2026 and the first fossil fuel fired power plant converted to geothermal steam in 2028.

That, at least, should be within my lifespan.

Articles of Possible Interest in *Vacuum Technology & Coating* Magazine

April 2010
Residual Gas Analyzers for Process Monitoring
Part 1 – Basics

May 2010
Residual Gas Analyzers for Process Monitoring
Part 2 – Integration with Vacuum Systems

June 2010
Residual Gas Analyzers for Process Monitoring
Part 3 – Applying RGAs to Process Systems

Articles may be accessed at http://vtcmag.com/. Scroll to the bottom of the page to the back issue selection box. Look for my columns and you will probably find other articles of interest.

End Notes

March turned out to be a busy month for me. I hope to spend more time around the shop and vacuum stand during the coming months. And, of course, contributions of any complexity are welcome.