HOT SPOTS, CHAIN EVENTS & MICRONUCLEAR EXPLOSIONS

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It is now generally accepted that LENR type nuclear reactions primarily take place on the surface (or in the near surface region) rather than in the bulk metal. Most researchers also subscribe to the notion that there is a special environment christened as “Nuclear Active Environment” or NAE by Ed Storms where various nuclear reactions appear to be taking place. What however is not spelt out clearly but seems to be commonly believed is that these NAEs are not created at the same instant throughout the surface region of the host metal but possibly produced in localized regions or hot spots during the dynamic diffusion of deuterons in and out of the metal or during any other type of triggering mechanism. Also it is unlikely that once a NAE is formed it is going to continuously catalyze nuclear reactions for all time to come. Thus the active life time of an NAE is of interest: Does it last for nano secs, microsecs, minutes or hours? The nature of the NAE continues to be elusive.

At ICCF 1 and later at Provo (both meetings held in 1990) the BARC group first presented results based on their tritium and neutron measurements, especially the multiplicity distribution of neutron output, that suggested that micro nuclear explosions seem to be taking place at localized hot spots which generate both Tritium and neutrons (subject to the n/T branching ratio anomaly) in Ti targets. The rationale for arriving at the micronuclear explosion hypothesis has been re-presented by this author in a comprehensive review paper included in the forthcoming ACS LENR Sourcebook Vol 2 (2009) Edited by Jan Marwan and Steven Krivit. We have estimated that about $10^{12}$ to $10^{14}$ LENR reactions take place highly localized in space and time.

Since the 90s many other researchers (notably Mitch Swartz, Pam Boss) have reported observing hot spots in their excess heat producing cathodes, Although these authors themselves have not claimed that these hot spots could be due to nuclear reactions, it is tempting to speculate that perhaps the concept of micronuclear explosions is applicable to heat generating helium producing reactions too. One can easily estimate for a hot spot to be detected, how many nuclear reactions should take place at a given spot in a very small time duration?

On the theoretical side, many models especially those which depend on the catalyzing role of some exotic particle (Erzions, poly neutrons, trapped neutrons etc) also seem to point to the possibility of occurrence of chain events. In any case two decades into CMNS it may be worthwhile examining the merits of the micronuclear explosion hypothesis and seek experimental evidence to either rule it out or have it confirmed.
“HOT SPOTS, CHAIN EVENTS AND MICRONUCLEAR EXPLOSIONS”

Mahadeva Srinivasan
(Formerly of BARC, Mumbai)

ICCF 15,
Roma, Italy

7th October 2009
Previous Speakers at this meeting who have already alluded to Chain Events

- Robert Duncan (Craters Cavities)
- Y.Kim (BEC)
- Akito TAKAHASHI
Speculations on Characteristics of NAE

• Two decades into the CF/LENR/CMNS era, the mechanism behind these reactions still eludes us!
• General agreement that phenomenon occurs on surface, in “special” regions - NAEs by Storms.
• One could *speculate* that spatial extant of the NAE could possibly be a single nano particle or a grain.
• Reasonable to expect that all NAEs wont be created simultaneously all over cathode surface.
• Similarly, once formed, NAEs cant be expected to continue catalyzing reactions for “ever & ever”.
• The NAEs must have a finite “active” lifetime!
• Could this be *ns, μs, seconds, hours, days*?
Hot Spots, Chain events, Micronuclear Explosions

• This line of *speculation* leads us to *postulate* that the LENR phenomenon could comprise of a series of “bursts” of nuclear reactions, each burst composed of “X” nos of nuclear reactions generated by each NAE during its lifetime.

• What could be the temporal characteristics of the reactions *within* a single nuclear “burst”?

• Could these individual reactions be “chain correlated” with each new reaction triggered by the previous or other “exotic” agent or particle?

• Alternately the entire “X” numbers of reactions could take place simultaneously (coherently?) in a flash… a sort of micronuclear explosion (MNE)!
REVISIT EARLY BARC STUDIES (1989-90)

• Is there even a shred of experimental evidence to suggest the occurrence of such MNEs?

• Indeed many experimenters in recent times have reported observing “hot spots” (Swartz, SPAWAR group etc) although they have not claimed that these may be attributed to nuclear phenomena.

• However the old timers here will recall that we at BARC had published experimental results indicative of the occurrence of MNEs, within a few months of the F & P announcement!

• Karlsruhe (July ‘89), BARC 1500 report (Aug ‘89), ICCF-1 (March ‘90), FT (Aug ’90), Provo (Oct ’90)

• Paper appearing in ACS LENR Sourcebook II (‘09)
HIGHLIGHTS OF EARLY BARC WORK

- On March 24th 1989, 12 teams (~ 50 scientists) took up the challenge of verification of the “nuclear origin” of Fleischmann-Pons Effect!
- Within months all teams reported both n & T
- BARC was among first groups to find branching ratio anomaly, \((n/T) = \sim 10^{-7}\)
- In the next few projections I recapitulate the various elements of the puzzle that led us to conclude that MNEs could be occurring!
- (Some of these slides were presented already last year at ICCF 14 during my review of the history of Cold Fusion in India !)
# BARC ELECTROLYSIS EXPERIMENTS (1989-90)

<table>
<thead>
<tr>
<th>Division</th>
<th>Matl</th>
<th>Cathode:</th>
<th>Geom</th>
<th>Area</th>
<th>Anode</th>
<th>Neutron Yield</th>
<th>Tritium Yield</th>
<th>n/T Ratio</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Ti</td>
<td>Rod</td>
<td>104</td>
<td>ss pipe</td>
<td>3.10e+7</td>
<td>1.4 10e+14</td>
<td>2.10e-7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pd-Ag</td>
<td>Tubes</td>
<td>300</td>
<td>Ni Pipes</td>
<td>4.10e+7</td>
<td>8.10e+15</td>
<td>5.10e-7</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>300</td>
<td></td>
<td>9.10e+7</td>
<td>1.9 10e+15</td>
<td>5.10e-7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>78</td>
<td>Porus Ni</td>
<td>5.10e+4</td>
<td>4.10e+15</td>
<td>1.2 10e-9</td>
<td></td>
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<tr>
<td>5</td>
<td>Pd</td>
<td>Hol.Cyl.</td>
<td>5.9</td>
<td>Pt Mesh</td>
<td>3.10e+6</td>
<td>7.2 10e+13</td>
<td>4.10e-8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Cube</td>
<td>6.0</td>
<td></td>
<td>1.4 10e+6</td>
<td>6.7 10e+11</td>
<td>1.7 10e-4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Pellet</td>
<td>5.7</td>
<td></td>
<td>3.10e+6</td>
<td>4.10e+12</td>
<td>1.10e-4</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Ring</td>
<td>18</td>
<td></td>
<td>1.8 10e+8</td>
<td>1.8 10e+11</td>
<td>1.10e-3</td>
<td></td>
</tr>
</tbody>
</table>

Electrolyte: *5M NaOD @ 0.1M LiOd
NEUTRON COUNT “SPIKES” DURING RUN NO. 1

MILTON-ROY Pd-Ni ELECTROLYTIC CELL (21st APRIL 1989)

PROTON RECOIL COUNTER

BF3 BANK

COUNTS / 5 MINS

TIME (HOURS) →
BARC FINDING # 1

- Neutron to tritium ratio (n/T) \( \sim 10^{-7} \)*
- This basically means that on an average, one neutron is emitted for every 10 million tritons!

* Confirmed since by many groups!
NEUTRON SPIKE & TRITIUM OUTPUT (ROMG CELL)

11 mm Cyl. Pd Pellet cathode - 13th Feb 1990

- Measured tritium value in cell solution.
- Calculated tritium value for expected conc.

Graph showing tritium DPM/ML (×10^3) and BF3 signal counts/sec.


- Background
- Signal BF3
- Neutron burst

2 hours duration
NEUTRON SPIKE & TRITIUM YIELD DURING RUN NO. 2
(Milton-Roy Cell - 12th June 1989)

The graph shows the total tritium yield and neutron counts over time. The tritium yield decreases sharply after the initial spike, reaching a low point around 40 hours, then remains relatively stable before spiking again. The neutron counts, on the other hand, start low, spike sharply at around 80 hours, and then level off to a peak of 457 nCi on 9th July.
MILTON ROY CELL : NEUTRON SPIKE EPISODE
50 HRS AFTER CURRENT PUT OFF (16th June 1989)
Multiplicity Distribution also Measured
BARC FINDING #2

- Production of neutrons and tritium appears to be connected in some way.
- The fact that we detect neutrons first and tritium later is because electrolyte samples are taken only periodically for tritium assay!
- They could have appeared at the same time or one could have “closely” followed the other.
- But since tritium is more prolific, reasonable to speculate that one neutron is generated for every $10^7$ tritons through some very low probability secondary reaction!
“Observation of High Multiplicity Neutron Emission Events from Deuterated Pd and Ti Samples”

(I was led to think along these lines since my Masters thesis 25 years earlier had been on “Neutron Density Fluctuation Studies in Zero Energy Reactor ZERLINA” – in a field called “Reactor Noise Analysis”!)
INVESTIGATION OF STATISTICAL CHARACTERISTICS OF NEUTRON EMISSION

• Are the neutrons emitted one at a time in a random fashion following Poisson distribution?

• Or are there neutron “bursts” wherein many neutrons are emitted in a bunch implying chain reaction events?

• Experimental method exploits fact that the slowing down time of fast neutrons in moderator assembly surrounding a thermal neutron detector is $\sim 30 \mu s$!

• Hence two or more neutrons from same event get separately detected.
ANALOGY OF NEUTRON SOURCES

• Am-a-Be source throws out one neutron at a time following Poisson statistics whereas Cf-252 spontaneous fission neutron source produces several neutrons (3 to 10) at a time.

• In safeguards field Plutonium content of sealed packages detected through its Pu-240 isotopic content using multiplicity distribution measurements.

• Theory and techniques well developed.
Theoretical Considerations
For Poisson Distribution (Random)

• If \( N_0 \) = count rate due to random events
• and \( t \) = counting time interval (say 20 ms)
• For case when \( N_0 t << 1 \)
• \( N_0 t \) = prob. of registering 1 count
• \((N_0 t)^2/2! = \text{Prob of registering 2 counts}\)
• \((N_0 t)^3/3! = \text{Prob of registering 3 counts}\)
• \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \text{and so on.}\)
• Note that prob of higher order multiplicities rapidly diminishes !!
Now let us suppose, superimposed on random background, there are:

- $s$ number of burst events/sec with
- $v$ number of neutrons in each burst and
- $\epsilon = \text{efficiency of neutron detection}$

Then the contribution of burst events to total count rate is $sv\epsilon$
Theory For Burst Events  
(Binomial Distribution)

• For \( v >> 1 \) and \( \varepsilon << 1 \)

• Prob \( P_r \) of detecting \( r \) neutrons out of \( v \) that are produced is given by

\[
P_r \ldots [(v\varepsilon)^r/r!]e^{-v\varepsilon}
\]

• This expression peaks for multiplicities (\( r \)) whose magnitude is close to the product \( v\varepsilon \)

• Thus if \( v\varepsilon \sim 4 \), the probability of detecting a multiplicity of 4 is actually higher than that of obtaining 3!
TABLE I

Expected Frequency Distribution of Counts for Poisson and Bunched Neutronic Events for Typical Sets of Parameters

<table>
<thead>
<tr>
<th>Multiplicity Of counts</th>
<th>Frequency of Counts in 20ms Intervals for $10^5$ samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poisson Events</td>
</tr>
<tr>
<td></td>
<td>$N_0=0.3$ cps</td>
</tr>
<tr>
<td>0</td>
<td>99940</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>$\sim10^{-2}$</td>
</tr>
<tr>
<td>3</td>
<td>$\sim10^{-9}$</td>
</tr>
<tr>
<td>4</td>
<td>$\sim10^{-9}$</td>
</tr>
<tr>
<td>5</td>
<td>$\sim10^{-13}$</td>
</tr>
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</table>
TABLE II

Frequency Distribution of Background counts in Two Detector Banks

<table>
<thead>
<tr>
<th>Multiplicity of counts</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BF$_3$ Bank</td>
</tr>
<tr>
<td>0</td>
<td>750035</td>
</tr>
<tr>
<td>1</td>
<td>339</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4-20</td>
<td>0</td>
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</table>

$N_0 = 0.023\text{cps}$

$N_0\tau = 5 \times 10^{-4}$
<table>
<thead>
<tr>
<th>Time</th>
<th>BF$_3$ Counter Bank (Signal)</th>
<th>$^3$He Counter Bank (Background)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Hrs)</td>
<td>1</td>
<td>2</td>
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<tr>
<td>18.55</td>
<td>124</td>
<td>21</td>
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<tr>
<td>19.00</td>
<td>54</td>
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<td>19.05</td>
<td>335</td>
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<td>82</td>
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<td>19.15</td>
<td>243</td>
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<td>19.25</td>
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<td>19.30</td>
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<td>19.35</td>
<td>447</td>
<td>42</td>
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<tr>
<td>19.40</td>
<td>104</td>
<td>13</td>
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<tr>
<td>19.45</td>
<td>355</td>
<td>49</td>
</tr>
<tr>
<td>19.50</td>
<td>395</td>
<td>99</td>
</tr>
<tr>
<td>19.55</td>
<td>55</td>
<td>24</td>
</tr>
</tbody>
</table>

(*) Starred numbers represent the multiplicity of counts obtained in a single 10 ms interval. The respective frequency of occurrence (per 1000 gated intervals) is given in the corresponding column below.
FREQUENCY DISTRIBUTION OF BURST COUNTS INTEGRATED OVER 30 DAY PERIOD (ICCF-5)
PRINCIPLE OF DEAD TIME TECHNIQUE

Train of pulses, as received from detector

Gate pulses provided by the Dead Time Unit (DTU)

Dead Time  Dead Time  Dead Time  Dead Time

Pulses after gating from Dead Time Unit

After Subtraction from the original train of pulses

No Burst  Burst of Two  Burst of One  No Burst

Burst Neutron Detection by Employing Dead Time Unit
CONCLUSIONS OF “n” MULTIPLICITY STUDIES

- Approximately 20% of neutrons produced could be attributed to high multiplicity events wherein > 20 neutrons are generated per burst!
- Although balance 80% of neutrons detected were single neutron detection events that still does not prove they were in fact emitted only as singles!
- For example if 10 neutrons emitted in a sharp burst, even a set up with 10% neutron detection efficiency will not be able to detect multiplicity!
POSSIBLE REASONS FOR NON OBSERVATION OF MULTIPLE NEUTRON EMISSION BY OTHERS

• **Q:** How come no one else has observed bunched neutron emission?
• **Ans:** *No one has attempted!*

• When neutron detection efficiency is as low as 1%, even if 100 neutrons are emitted in a single sharp bunch, you will still detect it only as a single neutron event;

• If 10 counts are registered during a one minute interval, it could imply (for 1% efficiency) either
  • there were 1000 single neutron emission events
  • or *there may have been 10 burst events each of which emitted 100 neutrons!*
BARC FINDING # 3

• Neutrons appear to be generated in bursts of 10s to 100s;

• Since \(n/T\) is \(10^{-7}\), it follows that Tritium must in turn be produced in bursts of \(10^8\) to \(10^{10}\)!

• They are correlated in time; But what about space?
SPOTTY SIGNATURES OF
DEUTERATED TITANIUM
TARGETS
(Gas/Plasma Loaded)

Autoradiography was used
as a very effective tool!
AUTORADIOGRAPH OF A DEUTERATED Ti SHAVING INDICATING TRITIUM – CONTAINING HOT SPOTS
AUTORADIOGRAPH OF Ti ANODE OF PLASMA FOCUS DEVICE AFTER DISCHARGE SHOTS
BARC FINDING # 4

• In case of titanium targets, tritium is found in cold worked defect sites ... hot spots.
• These hot spots can perhaps be identified as “NAE” sites.
• The generated tritium stays put in same spot for several months! (poor diffusion rate in titanium)
• Superimpose finding No.3 on finding No.4, namely that tritium is found in highly localized hot spots which serve as NAE sites, and

• We are tempted to speculate that MNEs could be occurring in a single NAE site or possibly a single nano particle, producing approximately $10^8$ to $10^{10}$ tritons!

• Can we now jump and speculate further that heat producing helium generating reactions also could occur in form of MNEs? Do the temperature hot spots on cathodes give a clue?
ESTIMATED MAGNITUDE OF MNEs

• We thus arrive at the conclusion that at an NAE site somewhere between $10^8$ to $10^{10}$ tritium producing reactions take place in some sort of avalanche type nuclear reaction or MNE (within a time span of nano seconds)

• It is for theoreticians to come up with a mechanism for such chain/MNE events!
CONCLUDING REMARKS

• My purpose in re-presenting this “forgotten old work” is to try and encourage/inspire at least one other group to attempt measurement of neutron multiplicity in an LENR configuration which produces neutrons.

• We have seen it in Pd-D2O electrolysis as well as TiD2 gas loaded targets. It would be interesting to see if gas loaded Pd nano powder based devices also generate neutrons; If so they would also become candidates for multiplicity measurements.

• Detection of non-Poissonian neutron bursts would imply possible presence of chain events & MNEs.

• Cant think of any other nuclear signatures for this.

• MNEs, if real, clearly pose challenge to theory!
THANK YOU!

My apologies for having been a bit too imaginative and speculative today!!