Sporadic Neutron Production by Pressure-Loaded D/Ti Systems under High Rates of Temperature Change

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Outline

- Introduction
- 1991 Results
- Experimental Setup 2012
- Data Acquisition Setup
- Results
- Conclusion
1991 experiment at the University of Missouri showed large neutron output during temperature shocking of titanium.

- Does not depend upon high-power electrical sources, radioactive materials or nuclear fission.
- Technology is portable – depends on addition of deuterium gas and temperature.

- 42 grams of 99.5% pure titanium sponge was load with deuterium.
1991 Experiments

- The chamber was moved from a liquid nitrogen bath and placed in the center of a neutron counting chamber using two helium-3 detectors. (Geometrical and Detector Efficiency ~ 4%)
Event Timing Card (ETC) Custom Built
- 32k count capacity with 1 μs resolution
- Decade counter
  - 1 million count capacity
Results from 1991 (Taking Geometrical and Detector Efficiency into Account)

- First run produced no neutron burst
- Second run produced large amount of neutrons
  - Between 0.21 and 2.25M n/s rate over 5 minutes (from source) and started during temperature shocking
- Third run also produced neutrons
  - Burst at 47,715 seconds into experiment of at least 1.27M neutrons (from source)
- Fourth run produced a small burst of neutrons
  - 4000 neutron burst during temperature shock
1991 Results

- Tritium content
  - 0.9\(\mu\)Ci above background tritium count from supply gas using liquid scintillation with the MU Health Physics department
ETC and Decade Counter Data

ETC Counts & Decade Counter Average Count Rate 1991

Experiment

Times When ETC Was Started and Saturated

Start of Thermal Shock

Approximate Count Rate from Decade Counter Observation
Material--Titanium

Three types of Ti were used. Granules and sponge Ti required to remove oxide layers to provide paths of deuterium absorption.
Experimental Setup

- Experimental Chamber
- Thermal Shocking Apparatus
- Diagnostic equipment
  - Physical parameter measurement
  - Radiation detection equipment
  - Radiation protection & dosimetry equipment.
Experimental Chamber

- Pump
- 0.125” type K Thermocouple, T1
- 0.125” type K Thermocouple, T2
- 0.375” SS 316L union tee
- 0.375” SS 316L Cap/loading port
- 0.375” SS 316L tubing
- Titanium loaded region
- Pressure gauge
- Tritium catch Tank (10mL)
- Deuterium gas

P
Thermal Shocking Apparatus
Physical parameter measurement

- Two Type K Thermocouples
  - Monitor the temperatures inside and outside the experimental chamber.
- Model: A Druck DPI 104 pressure gauge
  - Range: 0 to 10,000 psi
Diagnostic equipment

- Radiation detection equipment
  - Helium-3 detector with Polyethylene moderator
  - Ludlum BF$_3$ Neutron detector
  - CR-39 Chips
  - Sodium Iodide (NaI) detector
  - Thermoluminescent Dosimeter (TLD) badge
Layout of data acquisition setup

- Pressure
  - Temperature, T1
  - Temperature, T2

- He-3 counter
- Nal

- Counting card
- Labview™
- SCA
- MCA
- Canberra Genie2K
Experimental procedure

1. Loading Ti into the experimental chamber in a glove box.
2. Setting up all experimental devices at proper position and keeping the system at a cryogenic temperature.
3. Thermal shock
The reported count rates are raw -actual counts measured. The geometrical efficiency and detector efficiency are not taken into account.

The geometrical and detector efficiency have not yet been determined but our best estimation is that the efficiency will be less than 0.4%.
**Run3 Total Raw Count Rate**

Titanium: Sponge  
Weight: 20.10 g  
Inert gas: Helium  
Number of trial: 3

<table>
<thead>
<tr>
<th>Elapsed Time (s)</th>
<th>Neutrons/ 100 ms</th>
<th>T (°C)</th>
<th>P (psia)</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>688.2-6179.9</td>
<td>164*</td>
<td>-158</td>
<td>92</td>
<td>LN before 1-1</td>
</tr>
<tr>
<td>18020.4</td>
<td>45</td>
<td>-94</td>
<td>167</td>
<td>During trial 3-1 (~10 s after shocking)</td>
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<tr>
<td>70760</td>
<td>30</td>
<td>-1.4*</td>
<td>184.4*</td>
<td>During trial 3-2 (~7 s after shocking)</td>
</tr>
<tr>
<td>90563.8</td>
<td>11</td>
<td>-158</td>
<td>90</td>
<td>LN before 3-3</td>
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</tbody>
</table>

* Maximum counts
Titanium: Dehydrided Ti powder (run 4-8)
Weight: 11.71 g
Inert gas: Helium
Number of trial: 2

<table>
<thead>
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<th>Elapsed Time (s)</th>
<th>Neutrons/ 100 ms</th>
<th>T (°C)</th>
<th>P (psia)</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>589-725</td>
<td>44*</td>
<td>-164</td>
<td>95</td>
<td>LN before 4-1</td>
</tr>
<tr>
<td>10833-11312</td>
<td>13*</td>
<td>-164</td>
<td>95</td>
<td>LN before 4-1</td>
</tr>
<tr>
<td>17929-18504</td>
<td>18747*</td>
<td>-164</td>
<td>95</td>
<td>LN before 4-1 (in LN for ~ 5 hrs, before shocking 45 mins)</td>
</tr>
</tbody>
</table>

* Maximum counts
NOTE: In liquid nitrogen around 3,000 sec before starting run 4-1 shocking,

Periodic increasing signals, 1.5 Million total raw neutron count over 10 min
Gas Release from Run 4

- Five Days after Run 4 the chamber was pumped down with a turbo pump and sealed under vacuum at room temperature. During the weekend pressure in the chamber climbed to 800 psi
  - The gas was captured in a catch tank
  - Commercial labs will not analyze gas because T was one of the requested elements
Conclusion

- Neutron bursts
  All runs except run two
  - At cryogenic temperature
  - Close to start of thermal shocking
  - During shocking
  - After shocking
A total of 1.5 million raw neutron counts in a 10 minute period were observed in run four.

Compare to the 1991 experiment, which produced ~290,000 raw neutron counts per second steadily over a five minute period.

The magnitude of raw neutron bursts was smaller than those observed in the 1991 experiments (but the 1991 detection system was more efficient).

The neutron burst in run four occurred during the loading phase at LN2 Temperature.
Host metal

- Dehydrided Ti powder was considered as the best host material among three types of titanium used in our experiments.
Observations

- The 1991 experiment and Run 4 of 2012 have large and sustained neutron emissions. Both observations are inconsistent with Fracto Emission.
1. Theory of nanoscale compression
   - Release of deuterium during phase change into crystal builds up high densities in interstitial spaces and defects leading to compression of deuterium.

2. Fracto-emission
   - Fracturing crystal and electrostatic potential drive nanoscale high voltage and current electrical discharges