Tritiated Gas Mixing for Z-GTS Fills and Gas Analysis Round Robin

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10/23/2018
Talk Outline

- Background
- Design and operation
- Characterization
- Applications
  - Complex-wide Gas Analysis Round Robin
  - Z Machine Gas Fills
  - Potential for tritium gas standards if needed
- Future work and questions to answer
Why do we need a custom Gas Mixing System?

- Previous gas blends came from one of two places:
  - Matheson Tri-Gas for standard gases
  - Savannah River Site for Tritium Gas blends

- In 2015, Matheson lost its vendor certification for Sandia
  - Our Gas Analysis Lab verifies all incoming gas cylinders

- Savannah River currently provides mixes in pre-prescribed blends and cylinders.

- Needed the ability to mix custom gas blends for customers
  - Z Machine Target Fills use a custom apparatus and a unique gas blend for each experiment

- A need arose for a mixing capability in house!
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Syringe Pump Gas Mixing Manifold initially designed for trace tritium capability

Syringe Pump System:
- Physical mixing for the gases introduced
- Able to pressurize which is not possible with diffusion mixing apparatus
- Allows for lower pressure gas sources required for $^3$He and T$_2$ due to receipt conditions from vendor
- Direct sampling capability for verification of gas fill concentrations
- Useful for both tritiated and non-tritiated gas mixes

- Several manifold configurations are utilized based on the pressure of the activity being performed
- High pressure (up to 1700 psig) and low pressure (up to 13 psig) configurations currently in use
Current system for tritium gas mixes- internal tritium contamination exists at low levels

Have secondary syringe pump which could be configured into a non-contaminated system
Pending System Updates

- Reduced volume manifold custom built at SNL-CA
  - Better transfer efficiency from the supply cylinder to the fill apparatus
- Supply of tritium gas from U-bed arrangement pending authorization and paperwork update
  - No $^3\text{He}$ contamination
  - Higher supply pressures possible
  - Delivery quantity currently limited by volume and pressure of tritium standards
    - Delivered at 630 Torr
    - Continually depleted with use
    - Ingrowth of $^3\text{He}$ with $T_2$ decay
- Improved Pressure Gauge needed to improve precision
  - Higher fidelity with better response
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Design Limitations from Lack of Characterization

- Designed and built for Z Machine fills on a short schedule
  - Characterization of the mixing parameters for the system was never completed beyond initial function.
- Initial experiments* set mixing times to a range from 15 to 24 hours
- During mixing, ~3% loss of the gas composition
  - O-ring seal on the syringe pump piston
  - Poses a potential hazard to the MOW
- Fabrication of the piston housing into a ventilation hood
  - Removed the hazard to the worker
  - Sweeps any leaks to the main exhaust system
- With ever increasing tritium quantities, the expected tritium released out the stack also increases, potentially creating environmental concerns

Better characterization was required to continue use for increasing quantities of tritium.

*performed by Henry Peebles
Both initial gas supply bottles were measured at the conclusion of the experiment. No preference for the supply gas was present after 1 hour of mixing. Both bottles showed similar fractions of D₂ and He.
Pressure Loss Results

- The gas mixing system was filled with D₂ to a starting pressure of 500 psig.
- The system was set to recycle at 35 cc/min and allowed to run for 1 hour (~6 minutes per complete cycle- expansion and compression)
- The volume of the syringe pump and the pressure of the system were monitored and recorded every seven minutes.

No pressure loss was measured above the noise level of the gauge during the hour of the mixing experiment.
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Gas Analysis Round Robin

- Round Robin to compare gas analysis techniques across the different sites
  - Cross-site validation, instrument performance comparison, identify best practices
- Good opportunity to test the mixing station concurrently
- Segregated effort into phases and started inviting other sites to participate
  - Phase 0: Analysis of 3 known gas mixtures from Matheson Tri-Gas
  - Phase 1: Validation and verification of SNL in-house gas mixes
  - Phase 2: Analysis of tritium blends for those sites that can accept them

<table>
<thead>
<tr>
<th>Site</th>
<th>Mixes Sent</th>
<th>Pressure</th>
<th>Cylinder Type</th>
<th>Date Shipped</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANL</td>
<td>Phase 0</td>
<td>24.7 psia</td>
<td>50 cc</td>
<td>07/02/18</td>
</tr>
<tr>
<td>PNNL</td>
<td>Phase 0</td>
<td>24.7 psia</td>
<td>50 cc</td>
<td>07/11/18</td>
</tr>
<tr>
<td>Omega at LLE</td>
<td>Phase 0</td>
<td>28 psia</td>
<td>50 cc</td>
<td>8/14/18</td>
</tr>
<tr>
<td>AWE</td>
<td>Phase 0</td>
<td>12.7 psia</td>
<td>500 cc</td>
<td>Pending shipping authorization</td>
</tr>
</tbody>
</table>
The Z Machine at Sandia National Labs
The Z Machine at Sandia National Labs

Z Machine Vacuum Section

Z Containment System

33 m

Z Gas Transfer System (Z-GTS)

ICF target

Explosive Closure Valve

Debris baffles
## History of Z Machine Target Fills

- Have provided 9 fills for Z Machine Experiments to date- 2 more planned for FY19

<table>
<thead>
<tr>
<th>Shot #</th>
<th>Date</th>
<th>Containment</th>
<th>Gas Fill (atomic %)</th>
<th>Gas Fill System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2822</td>
<td>06/27/15</td>
<td>Mock</td>
<td>D, 50.7% $^4$He, 4.7% $^3$He</td>
<td>Z-GTS</td>
<td>Containment &quot;Null Shot&quot;</td>
</tr>
<tr>
<td>2856</td>
<td>09/30/15</td>
<td>Explosive</td>
<td>D, 41.4% $^4$He, 12.8% $^3$He</td>
<td>Z-GTS</td>
<td>Measure Containment Effectiveness</td>
</tr>
<tr>
<td>2857</td>
<td>10/02/15</td>
<td>Uncontained</td>
<td>D, 9% $^3$He, 0.02%Kr</td>
<td>Z-GTS</td>
<td>Uncontained Torrance with $^3$He</td>
</tr>
<tr>
<td>2980</td>
<td>07/12/16</td>
<td>Explosive</td>
<td>D, 0.1% $^3$He</td>
<td>Z-GTS</td>
<td>Containment Confirmatory with $^3$He</td>
</tr>
<tr>
<td>2987</td>
<td>08/03/16</td>
<td>Explosive</td>
<td>D, 0.1%$^3$T</td>
<td>Z-GTS</td>
<td>Contained trace tritium</td>
</tr>
<tr>
<td>N/A</td>
<td>07/31/17</td>
<td>N/A</td>
<td>$^4$He, 2.5% D, 0.0022%$^3$T</td>
<td>TH3GA</td>
<td>Seed and Capture Experiment</td>
</tr>
<tr>
<td>3167</td>
<td>11/01/17</td>
<td>Uncontained</td>
<td>$^4$He, 2.5% D, 0.0022%$^3$T</td>
<td>Z-GTS + CV</td>
<td>Integration Ride-Along Experiment</td>
</tr>
<tr>
<td>3178</td>
<td>11/30/17</td>
<td>Uncontained</td>
<td>D, 0.1%$^3$T</td>
<td>Z-GTS + CV</td>
<td>Uncontained Trace tritium</td>
</tr>
<tr>
<td>3266</td>
<td>06/13/18</td>
<td>Uncontained</td>
<td>D, 0.5% $^3$T</td>
<td>Z-GTS + CV</td>
<td>Chamber Confined Trace Tritium</td>
</tr>
</tbody>
</table>

Ever evolving experiment designs and physics goals create a new requirement set for each target and as a result the Z-Gas Transfer System (Z-GTS) fill composition and pressure.
Gas Mixing for Tritium Fills on Z

- A template spreadsheet is used to calculate the required quantities of gas for each fill
- Multiple factors are considered to perform the fill calculation:
  - Volumes
    - System
    - Tritium supply
    - Z-GTS
  - Tritium supply concentration
    - Account for tritium decay
  - Pressures
    - Supply gases
    - final fill requirement
Potential Future Need of In-House Tritium Standards

- If the ability to obtain calibrated tritium gas standards is lost, the need for standards would still remain to meet Neutron Generator production requirements.

- A high level contingency plan was discussed:
  - Prefer calibration extension for current standards whenever possible
    - Easiest solution
    - Cost effective
    - Requires standards to continue performing beyond initial calibration lifetime
  - Second less preferred contingency would be to make standards in-house
    - Lengthy certification process
    - Small volume fills
    - Shorter calibration lifetimes
    - Requires tritium from Savannah River along with the ability to cross calibrate from some verified source
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Future Experiments and Questions to Answer

- Characterize the system to measure equilibration times for the smaller volume manifold from SNL-CA
  - Ensure complete mixing times are established before the next fill, January 2019
- How much does the lower volume manifold help increase the transfer efficiency?
- Research the potential for real-time sampling of the manifold mixture with an RGA system
  - May need a small leak gasket to minimize the depletion of the gases in the system
  - Characterize the effect of pulling gas samples from the mix on the final equilibrium state. Each sample would change the end state equilibrium.
  - With effectively small samples, can this effect be ignored?
- Can Liquid Nitrogen be used to increase the transfer of tritium to the mixing station?
Questions? Comments?