An ALE Formulation of Thermodynamic Interaction of the Neutrino Factory Mercury Jet in the Target Envelope

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Problem Statement:

Following the Successful Completion of the E951 and MERIT Experiments regarding Hg Jet Stability and Beam Interaction,

The following question is addressed (attempted to be answered)

In the real target system where pulses will be arriving, interacting with Hg jet and Hg pool (+ Jet interacting with pool

How does the “ambient” volume look after a while?

Will Hg vapors end-up occupying the volume impeding pion travel after being produced and coming out of the Hg jet target?
Conservative velocity estimates \( \sim 200 \text{ m/s} \) are expected.

\[ K.E. = \frac{1}{2} \rho \, dV \, U_r^2 = \Delta P \, \delta(dV) \]

\[ \Delta P \approx \alpha_v \, \Delta T/k \]

\[ \alpha_v = (\partial V/\partial T)_p \]

\[ \delta(dV) = \alpha_v \, dV \, \Delta T \]

\[ U_r^2/c^2 = 2 \, \alpha_v \, \Delta T^2 \]

\[ U_r = \sqrt{2} \left[ \alpha_v \, \Delta T \right] c \]
Challenges:

**Hg EOS that cross phase boundaries**
SESAME Library revisited in attempt to numerically describe the Hg phase diagram and introduce it to codes such as LS-DYNA

**Energy Deposition introduction into Hg jet/pool system**
mechanics of it has been solved by utilizing capabilities of different codes

**Implementation of Solenoid Tesla Field as part of same analysis**
we think we have a solution with “pseudo-angular” rotation of Hg jet providing magneto-confining pressure

**Trusting the predictions of the violent processes that we try to simulate**
excellent basis due to successful benchmarking of relevant experiments
does any Hg remains suspended??
NuF Hg Jet
Time = 0
Bubble Dynamics and Hg Jet/Pool
Local pressure outside formed bubble can be very high from beam energy deposition.

Excellent driver of implosion process.
“Exact” Solutions of Air Bubble Collapse/Oscillation

“Exact” solution of bubble contraction/expansion

Pressure generation

Bubble Oscillation Verification - Density Air Bubble Center

Bubble Oscillation Verification - Peak Pressure 36.8 MPa
Test data

<table>
<thead>
<tr>
<th>Case</th>
<th>Peak Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1, Sensor 1</td>
<td>27.0 MPa</td>
</tr>
<tr>
<td>Test 2, Sensor 1</td>
<td>27.2 MPa</td>
</tr>
<tr>
<td>Test 3, Sensor 1</td>
<td>25.8 MPa</td>
</tr>
<tr>
<td>Test 4, Sensor 1</td>
<td>26.6 MPa</td>
</tr>
</tbody>
</table>

Prediction 26.8 MPa
Simulation Predictions confirmed by the BNL Tests:

No shock develops!!

Implosion process very long (20+ ms)
Hydrostatic pressure limit ~270 psi (19 Atm) !!!
Prediction of Pressure Pulse at Sensor Locations

Predictions ahead of test ➔ within 5% !!!
Path Forward:

We feel that the simulation processes have been well benchmarked to extrapolate the analysis into the question of phase transitions

SESAME Library (Hg) EOS described numerically (user input into LS-DYNA)

Incorporate all effects (hydrodynamic, beam, solenoid field)

Quantify the ambient space for operational mode

............... To be continued