Methods - Pipe Gun

The pipe gun consists of:

• Gun Barrel - stainless steel alloy

• Cryostat - capable of reaching 8 K

• Guide Tube - single or multiple loop

• Diagnostics - 3 light gates, 2 cameras, one shock accelerometer

Pellet Formation:

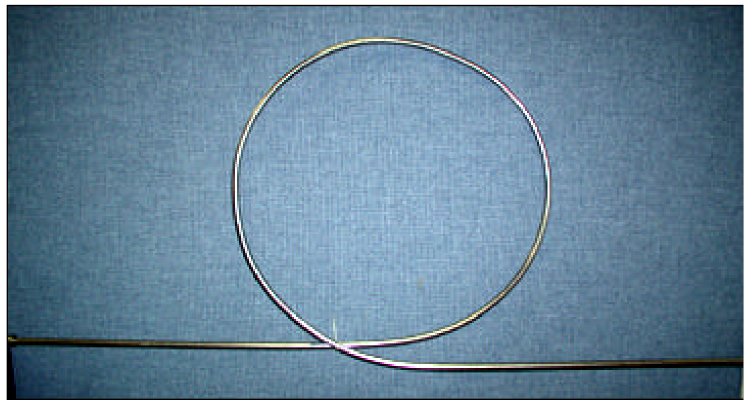
• Gas (at room temperature) is inserted into the gun barrel (usually at 25-45 K and below 10^{-3} torr)

• Cryostat cools narrow section of gun barrel to 8K

• Gas condenses and solidifies in cold region, forming solid ice pellet

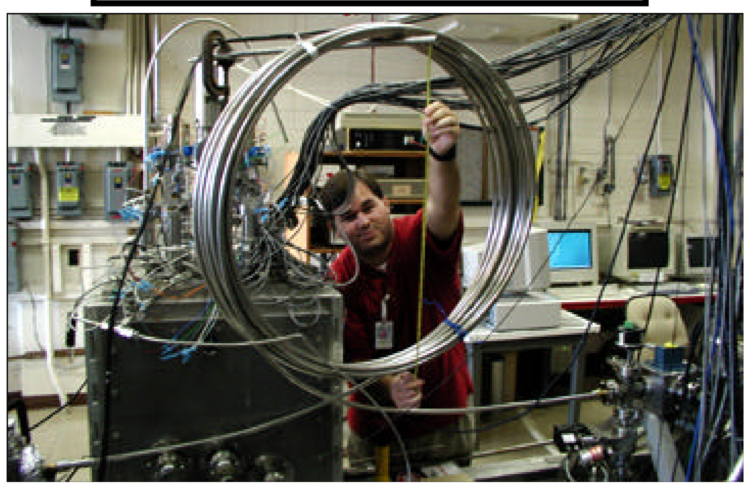
• Unused gas is vented

• Pellet is accelerated with a pneumatic punch and/or a puff of gas

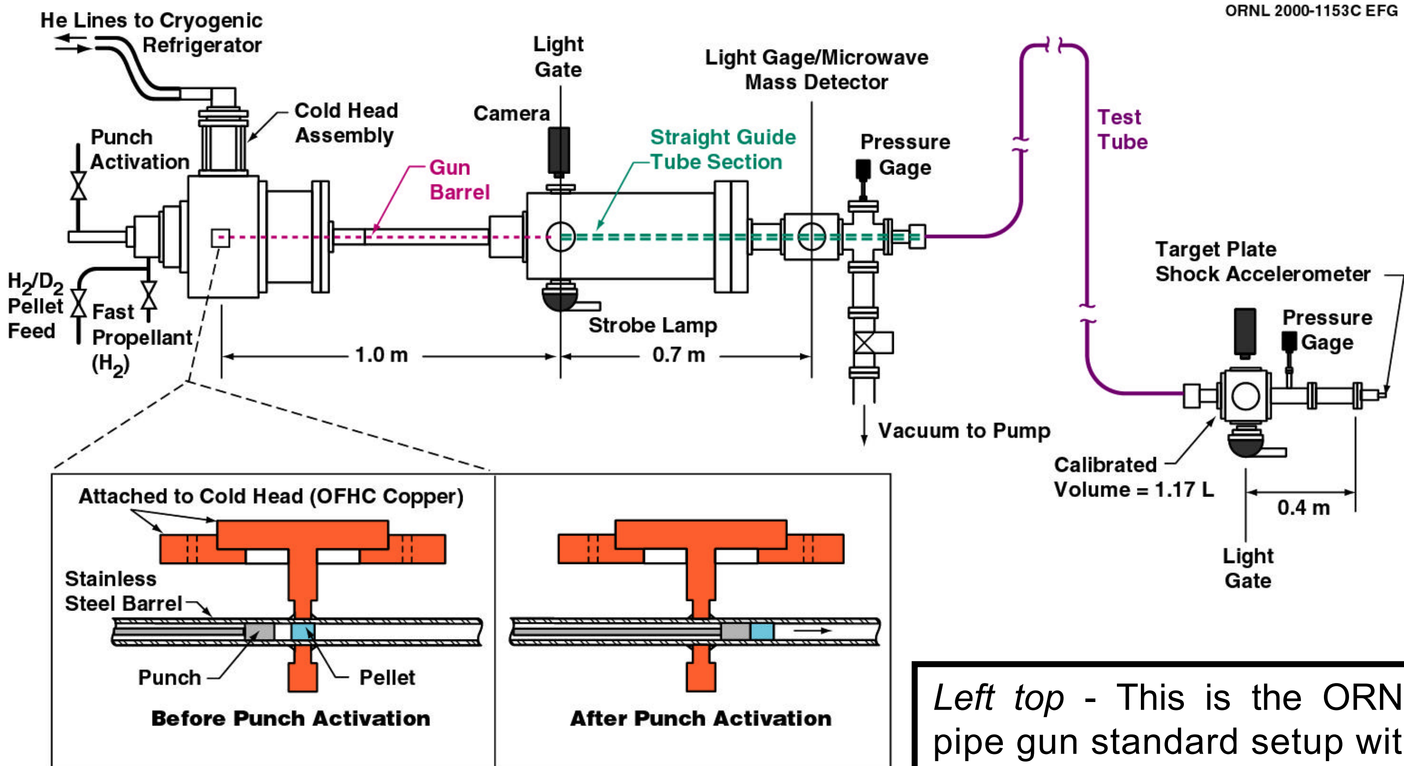


Top - Tube #1, single loop

Bottom - Tube #2, multiple loop



Materials - Pipe Gun



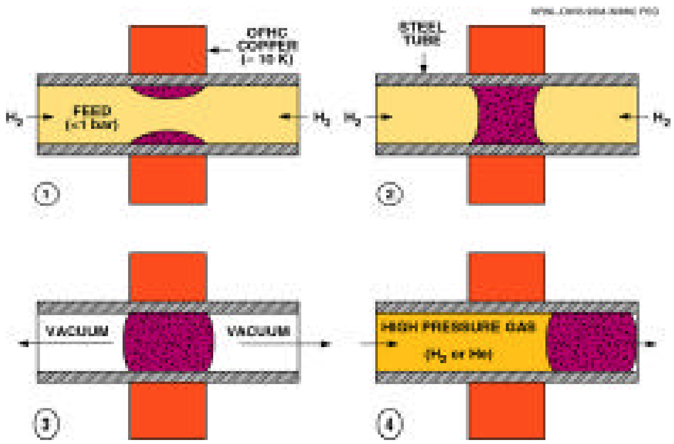
Guide Tube Parameters:

Tube #1: ≈3.79 m total, ≈0.61 m diameter, 1 loop

Tube #2: ≈30.5 m total, ≈0.81m diameter, 11 loops

Left top - This is the ORNL pipe gun standard setup with approximate measurements shown. Note that one camera is positioned at the end of the gun barrel, and the other is at the end of the guide tube.

Materials - Pellet Formation & Gas Properties



Pipe Gun – Simplest Pellet Injector
(Limited Number of Pellets)

Above - This illustration shows generally how pellets are formed inside of the gun barrel of the ORNL pipe gun. For this experiment a mechanical punch was usually used in place of or in addition to high pressure gas.

Below - This table lists important properties of the gasses used in this experiment. The most important properties are in red.

Isotope	H_2	D_2	Ne
Molecular weight (g/mol)	2.016	4.028	20.18
Critical-point temperature (K)	33.2	38.3	44.5
Triple-point temperature (K)	13.9	18.7	24.6
Triple-point pressure (bar)	0.072	0.172	0.432
Density (g/cm^3)	0.087	0.20	1.44

Materials - Neon Issues

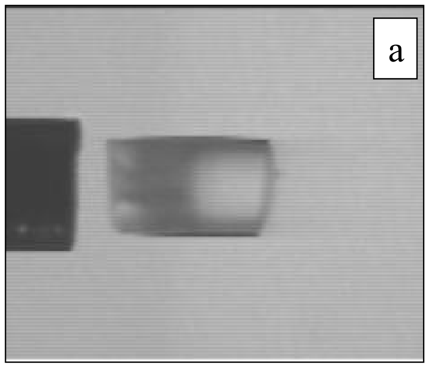
Hypothesis:

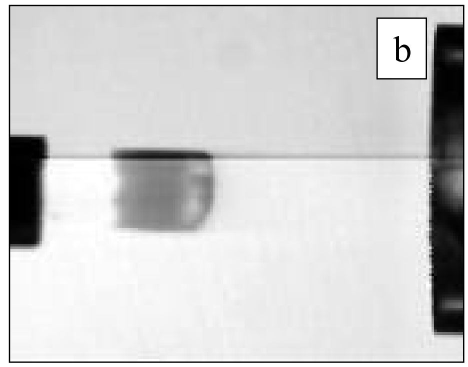
• Due to neon's high triple point, it is capable of freezing outside the cold region of the gun.

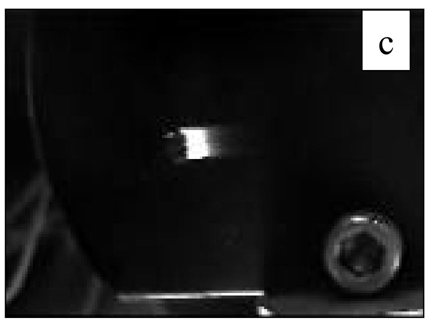
• The pellet forms and closes off outside the cold region, preventing the formation of the center of the pellet.

• The difference in temperatures creates a different crystal structure or density, which results in either opaque or clear ice

• The difference in crystal structure in the middle of the pellet, or a cavity in the middle of the pellet causes the pellet to break in the middle upon being shot.



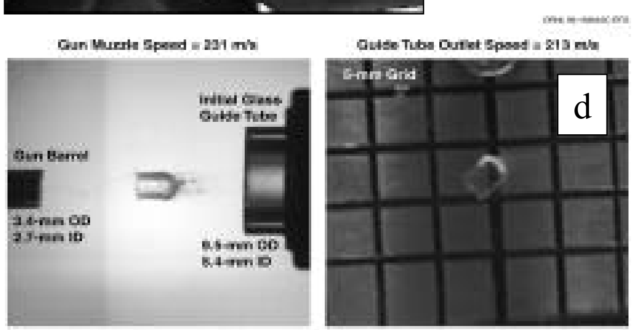




a) Ne pellet with "funnel" hole

b) Ne pellet with broken rear

c) Ne pellet with opaque and clear areas



d) a normal, clear H_2 pellet from the same pellet injector

Results - Tube #1 - Single Loop

Material	H_2	D_2	Ne
Inlet Speed Range (m/s)	220-570	145-410	60-165
Lowest Breaking (m/s)	370	225	70
Highest Survival (m/s)	475	310	110
Transition Range (m/s)	105	85	40
Lowest % Loss	1	1.5	5.5
Highest % Loss	15	7.6	12.5
Average % Loss	5.5	4.5	8.5

This chart shows the major statistics collected for each material from shots fired into Tube #1 (single loop). The most important statistics are in red. Please note that the percentage losses are *only* from speed comparisons of pellets that survived the guide tube *intact*.

Results - Tube #2 - Multiple Loop

- Since D_2 is the most commonly used gas in tokamak experiments, it was the only gas tested in Tube #2.

- Punch only injection yielded speeds around 200 m/s and completely shattered pellets.

- A combination of gas and melting yielded speeds between 45 and 175 m/s.

- Preliminary results indicate that pellets can survive up to 75 m/s without significant erosion or breaking.

- Results also indicate that D_2 pellets shot above 100 m/s typically will not survive.

- Due to the length of the tube and the injector setup, it was somewhat difficult to obtain reliable operation within the desired speed range.

- Further testing with this tube setup would provide more quantitative and precise definition of the speed boundaries for D_2 in this complex configuration.

Conclusions

• Results obtained from Tube #1 are comparable to those from previous experiments.

• Photographs of non-intact pellets suggest that D_2 and Ne are more likely to shatter and break than H_2. Very few D_2 and Ne pellets were observed to be eroded. However, H_2 is capable of differing degrees of erosion and breaking within the transition range.

• The limited data from Tube #2 show that it is possible for a D_2 pellet to survive in a long, continuous-curve guide tube at low speeds.

• The present pipe gun configuration is not sufficient for reliable testing in the speed transition region for long multiple-loop guide tubes (e.g. Tube #2). A method for consistently shooting "slow" pellets would be of great benefit.

• A necessary improvement is the development of a method for determining the exact mass of pellets before and after the guide tube to determine the nature and extent of the tube-pellet interaction and evaporation/mass loss of the pellet.

Acknowledgements and Information

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