Tritium Fueling Systems

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May 10, 2000

Plasma Fueling Program

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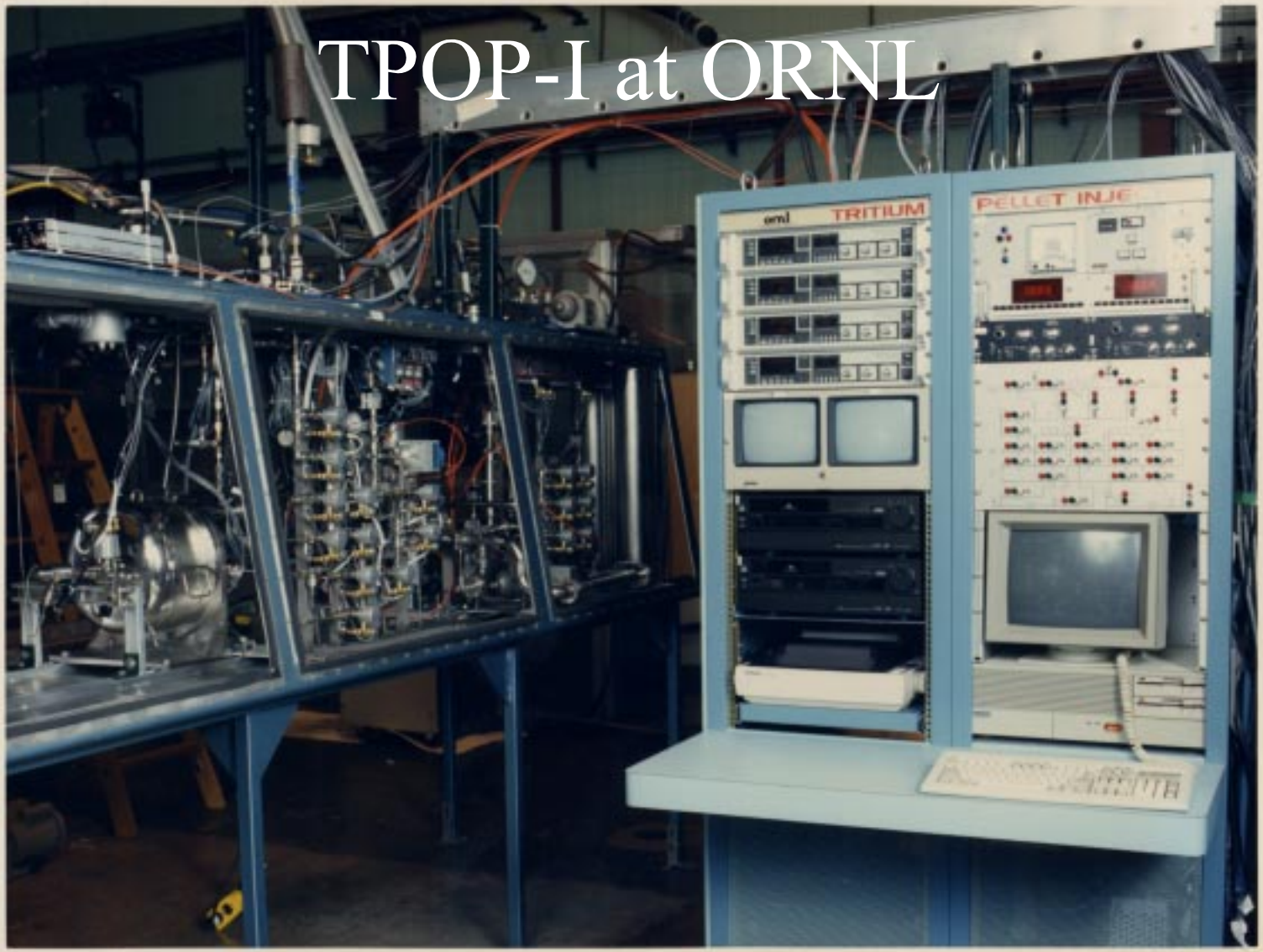
Tritium Fueling Systems

- Tritium Proof of Principle (TPOP-I)
  - ϕ4-mm pipe gun
  - Cryogenic He-3 separation
- Tritium Pellet Injector (TPI)
  - Pipe gun for TFTR based on TPOP-I design
- Tritium Proof of Principle Phase II (TPOP-II)
  - Extruder-based, ϕ8-mm Repeating Pneumatic Injector (RPI)

TPOP-I at ORNL



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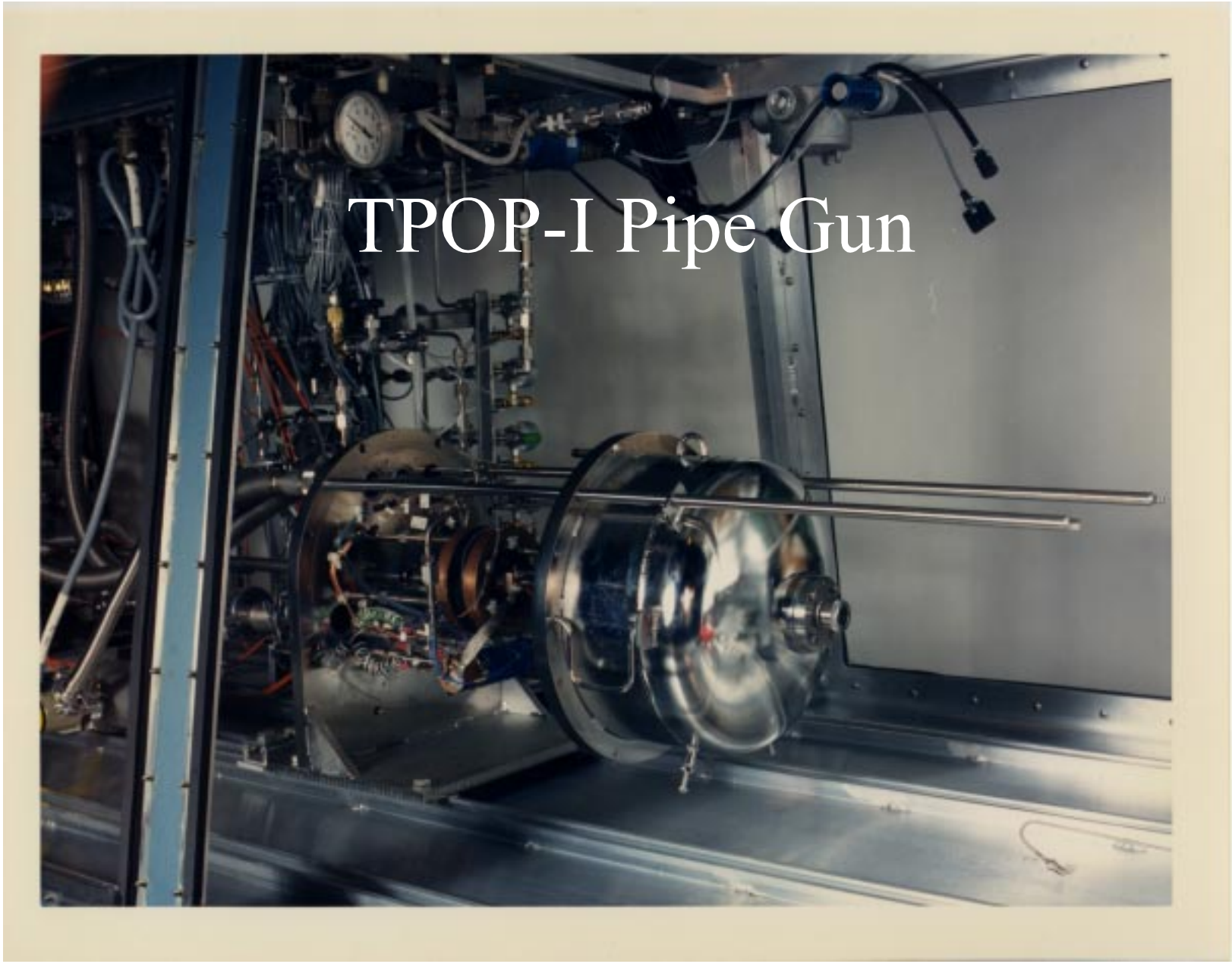
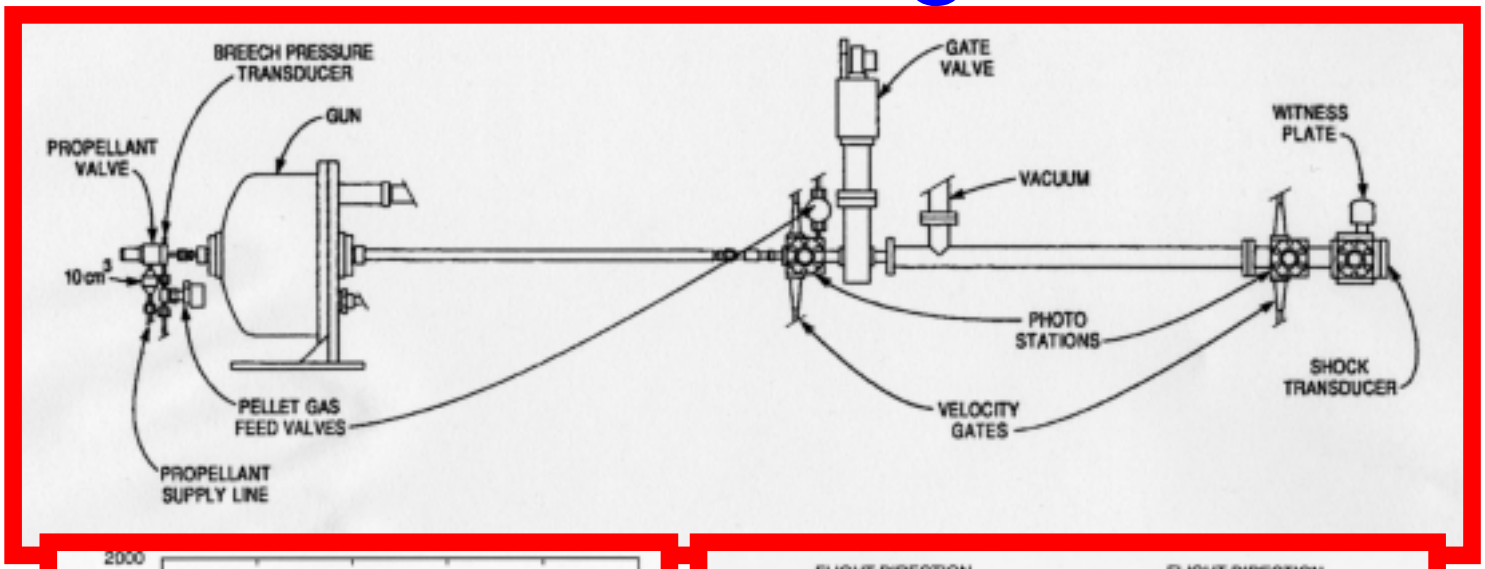
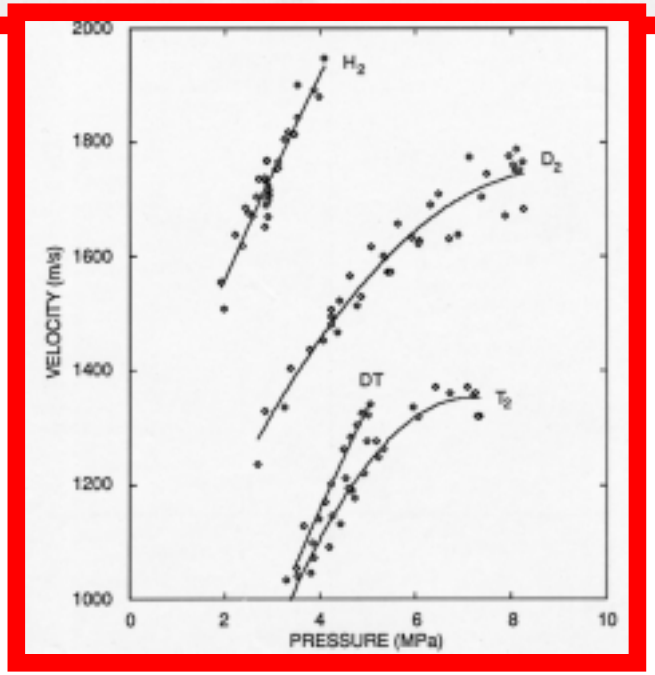
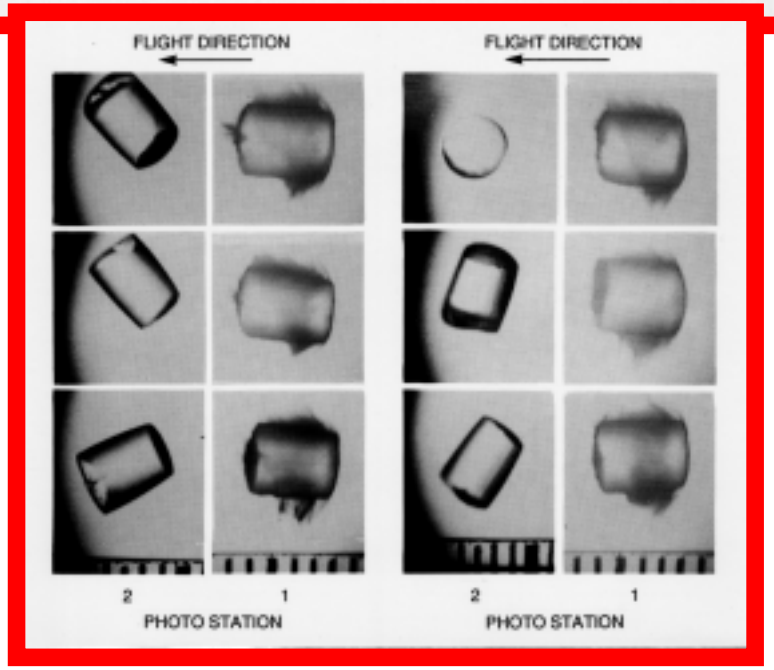

TPOP-I Pipe Gun

TPOP-I at TSTA

TPOP-I Pellet Diagnostics







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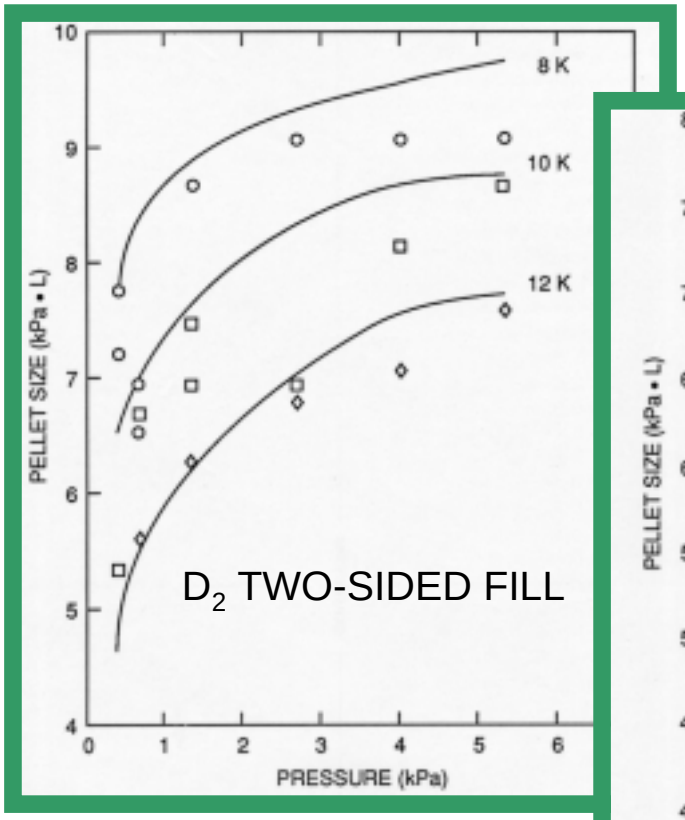
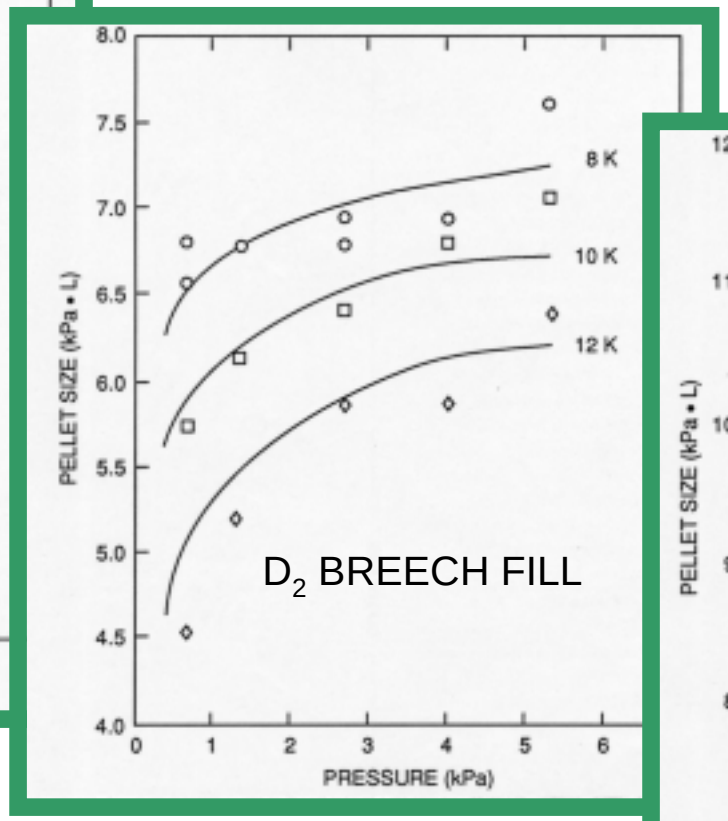
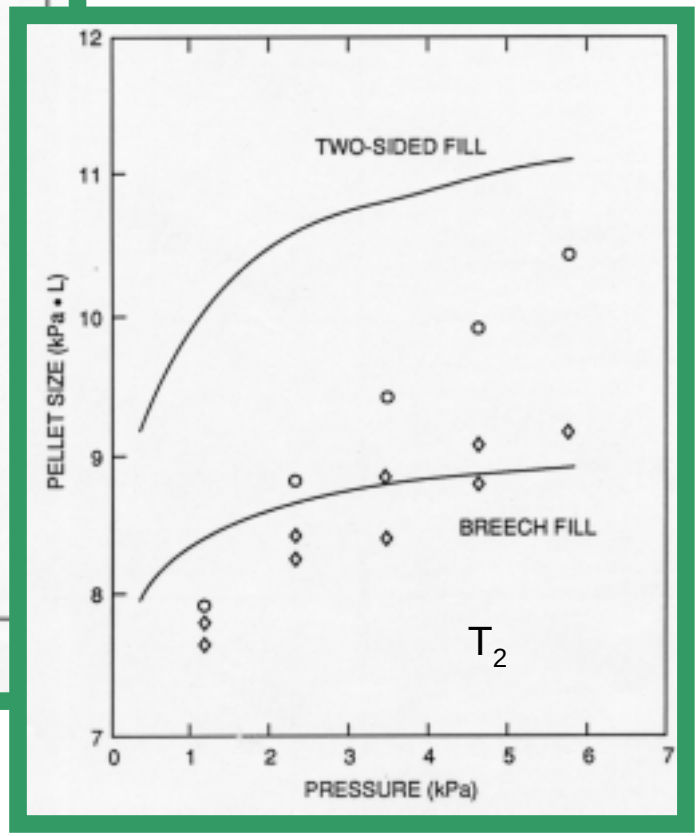
TPOP-I Equilibrium Pellets







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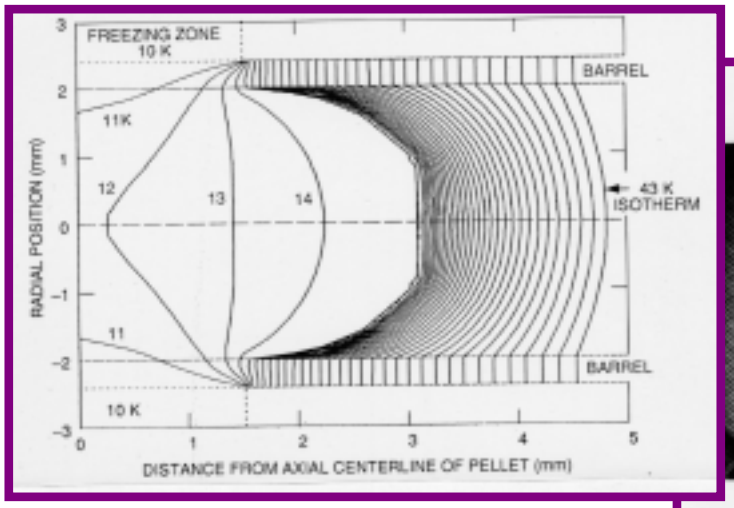
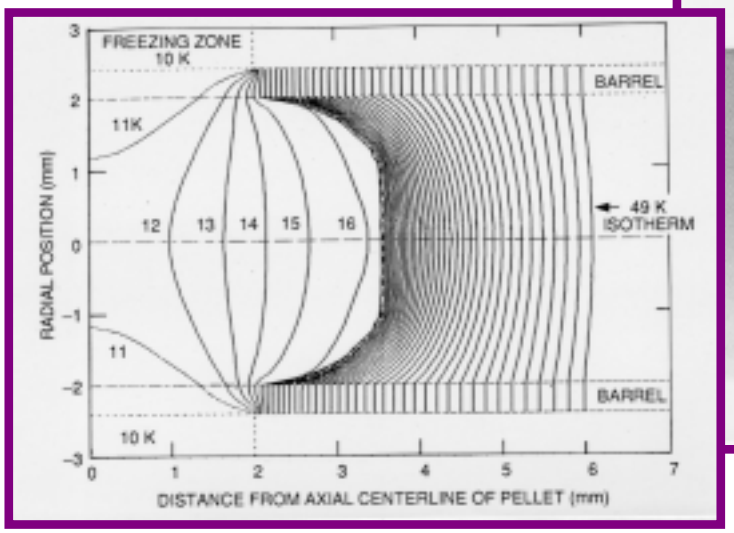
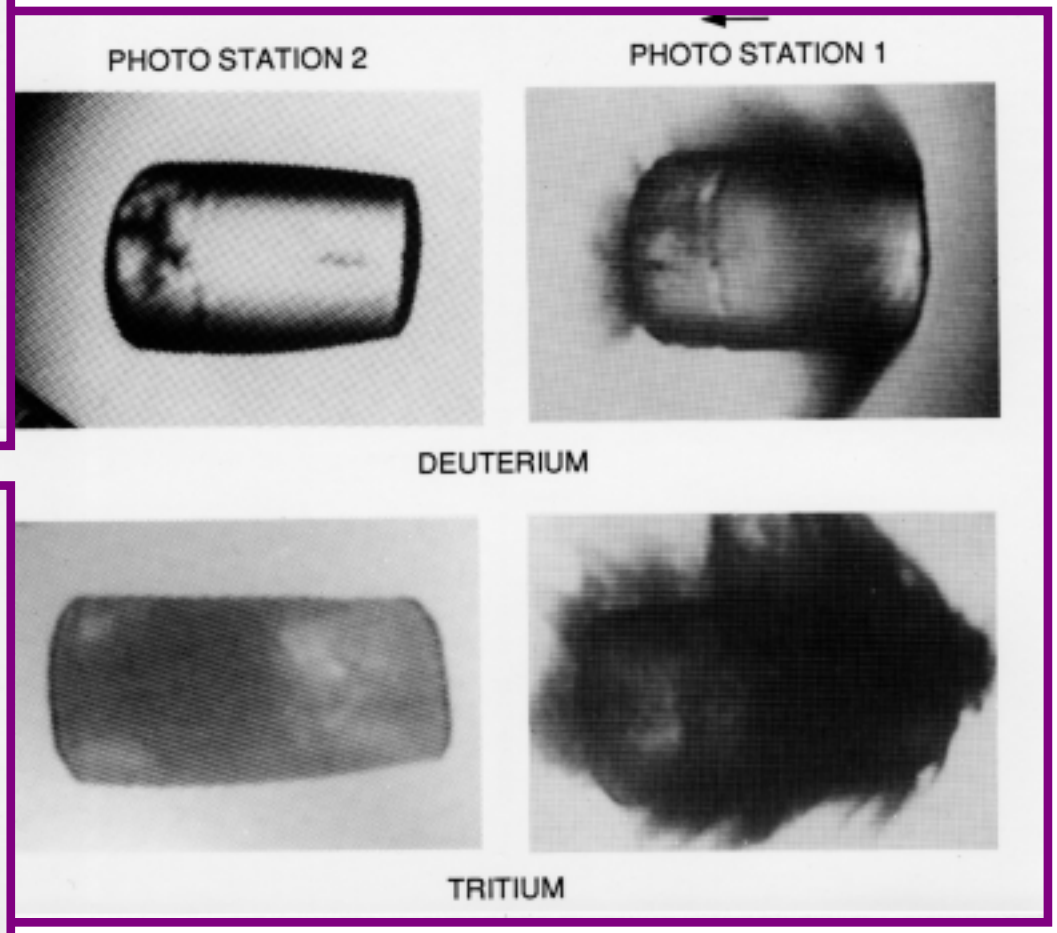
TPOP-I Equilibrium Pellet Size Model







Fill Pressure = 2.7 kPa (20 torr)

300 K heat sink 10 cm from freezing zone

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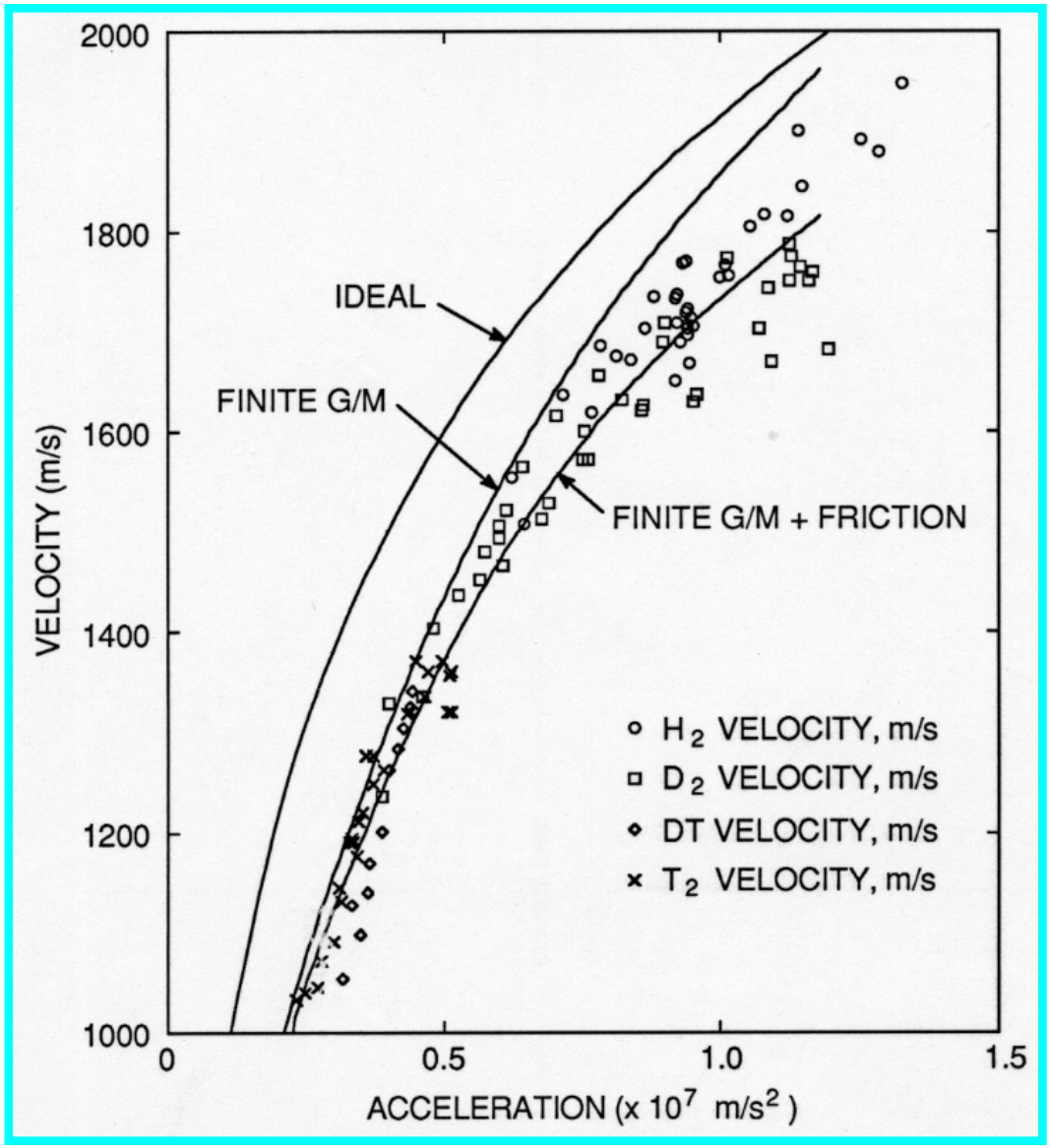
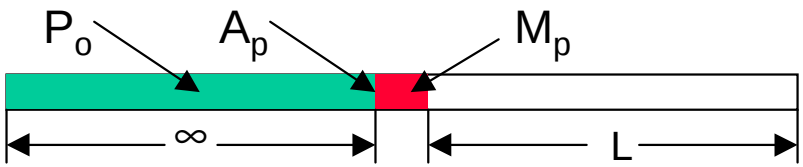
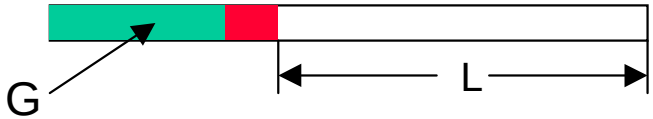
TPOP-I Pellet Speed Data



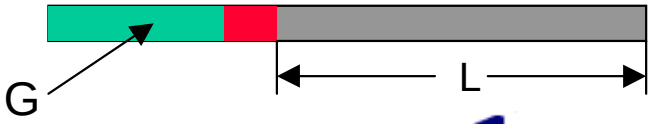
- **Ideal** Gun Model (Landau and Lifshitz)
  - $V = f(a_o) = f(P_o A_p / M_p)$



- **Finite G/M** Model (Seigel)
  - $V = f(a_o, G/M_p)$



- **Finite G/M + Friction** Model (U.S. Naval Ordnance Lab.)
  - $V = f(a_o, G/M_p, V/V_m)$



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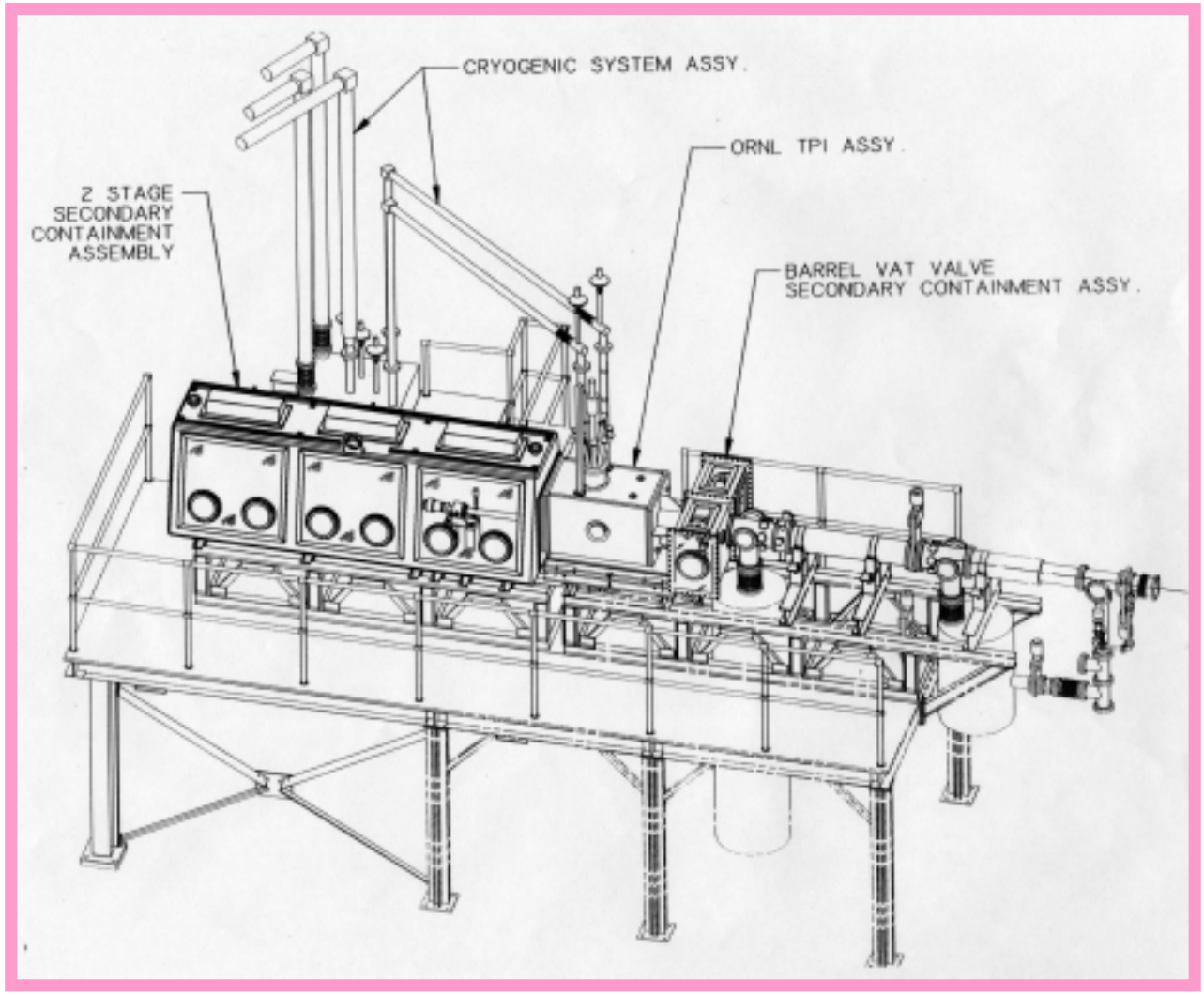
TPI – a tritium-ready pellet injector based on the TPOP design



- Four pipe guns to minimize tritium inventory
- Self-contained tritium handling system to control pellet size and perform cryogenic He-3 separation
- Glovebox secondary containment

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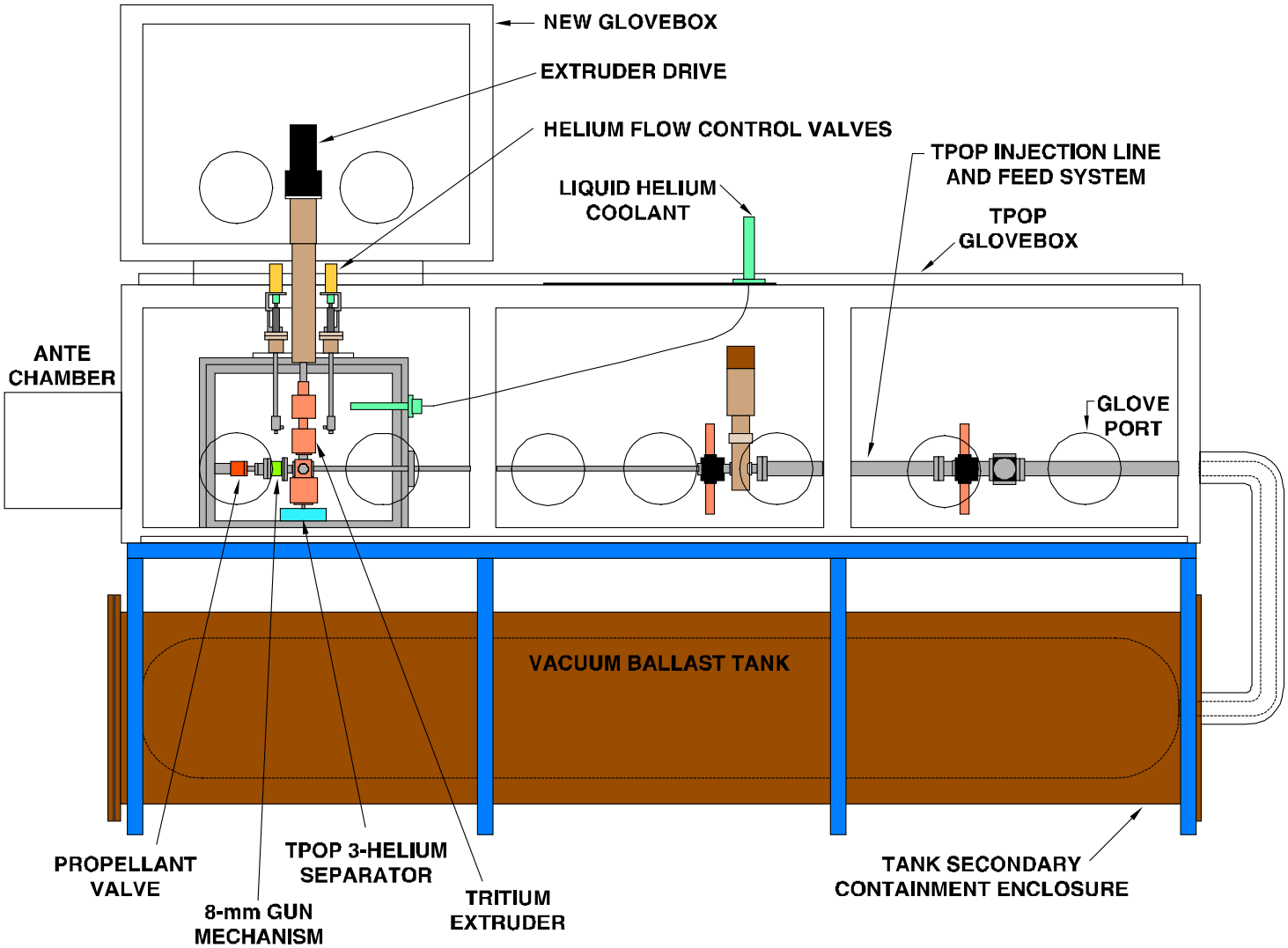
TPOP-II designed to test tritium extrusion and fit into TPOP-I envelope



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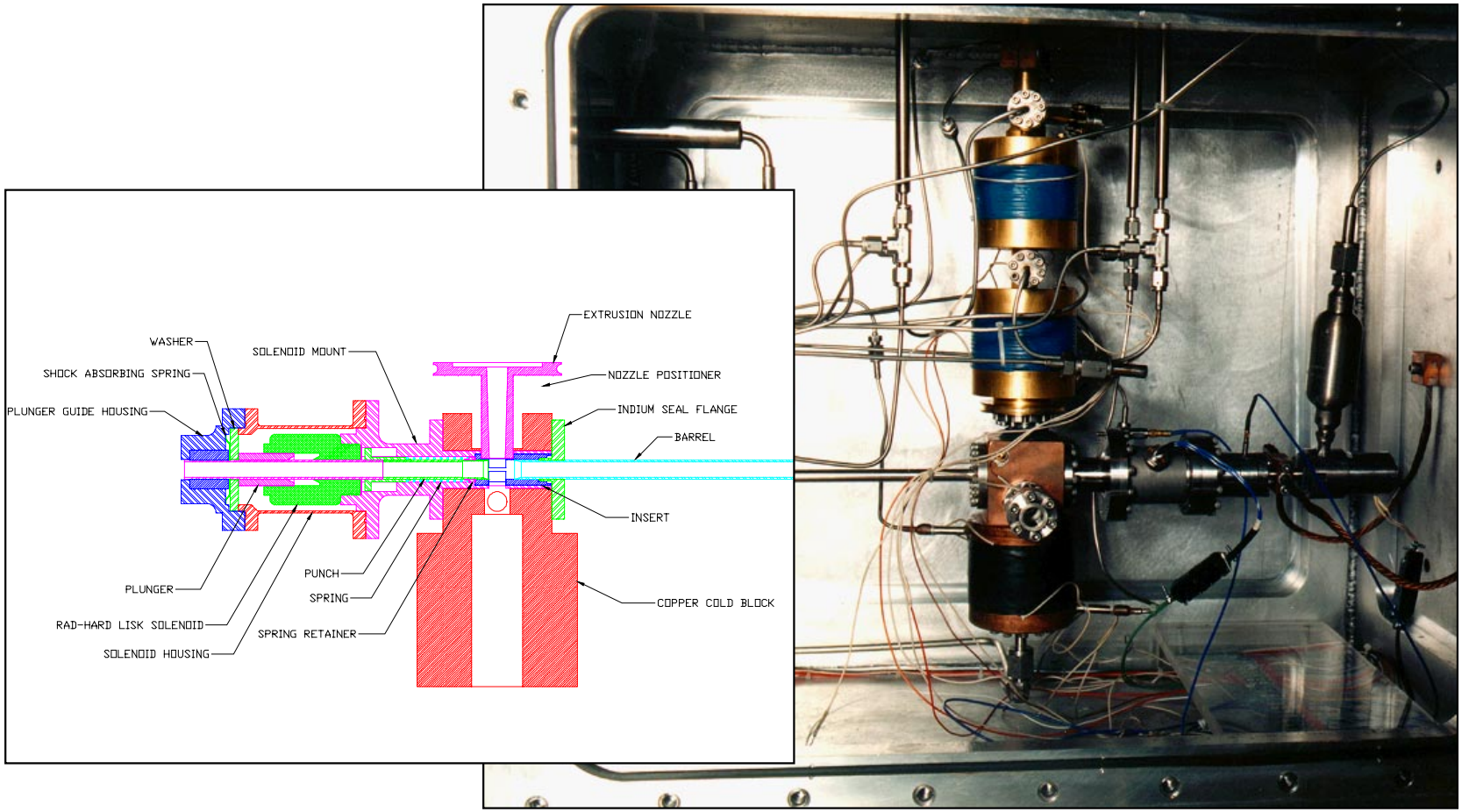
TPOP-II at TSTA

TPOP-II uses the RPI extruder and cookie-cutter concept



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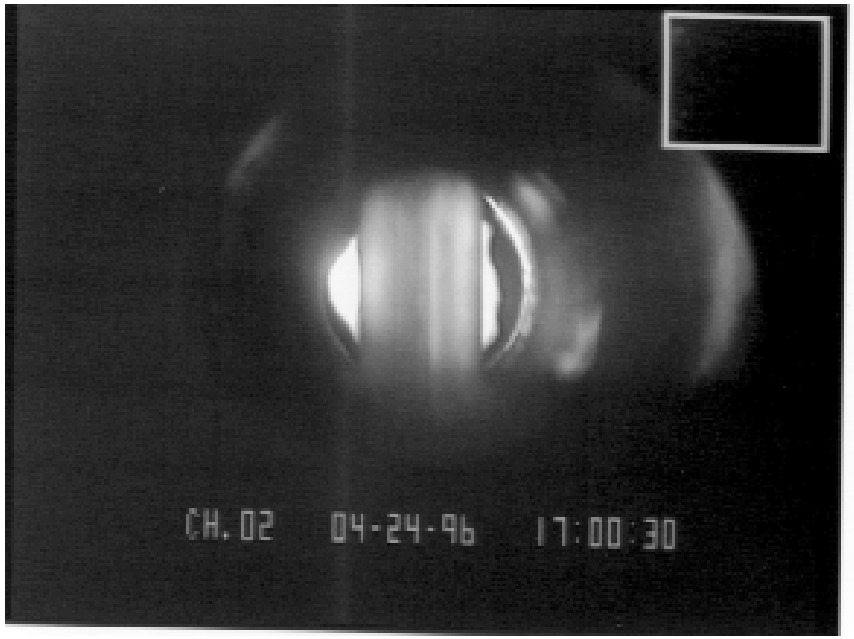
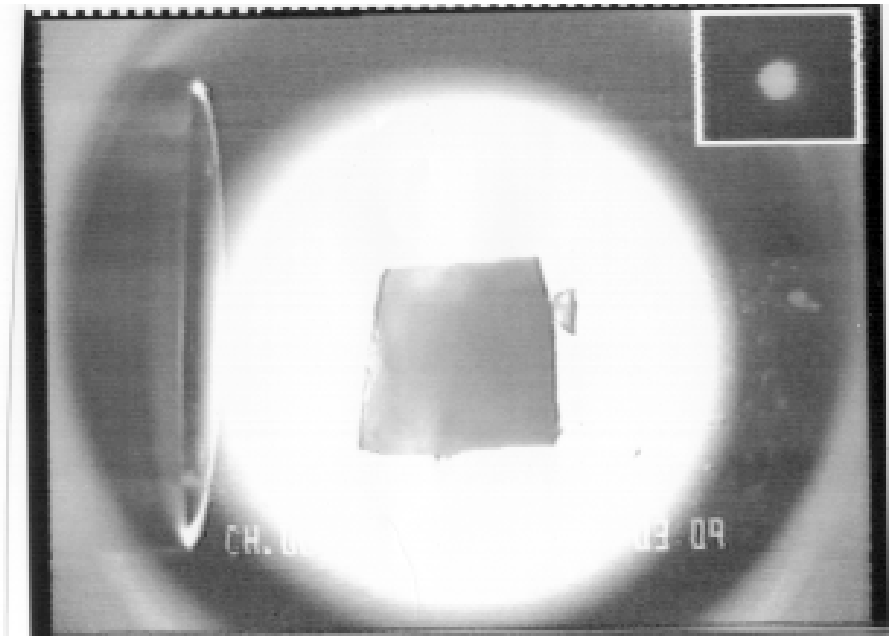
TPOP-II Extruded Pellets





Pure T_2 extrusion and pellet

D_2 pellets: 0.5 Hz and 1.1 km/s

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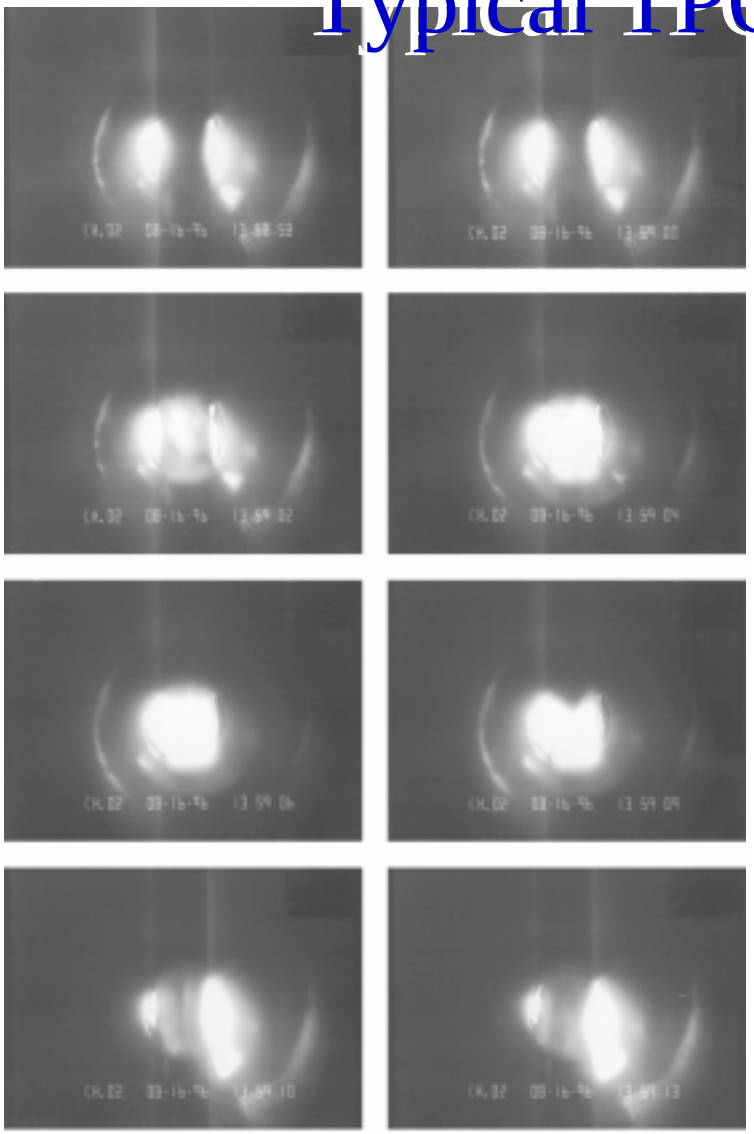
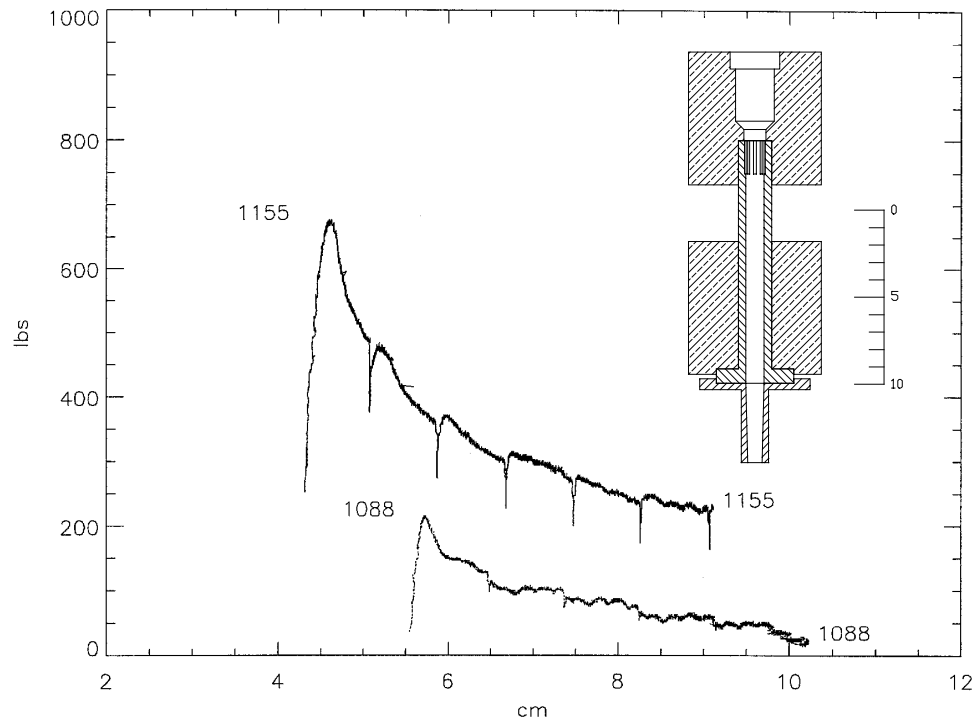
Typical TPOP-II Extrusion Data



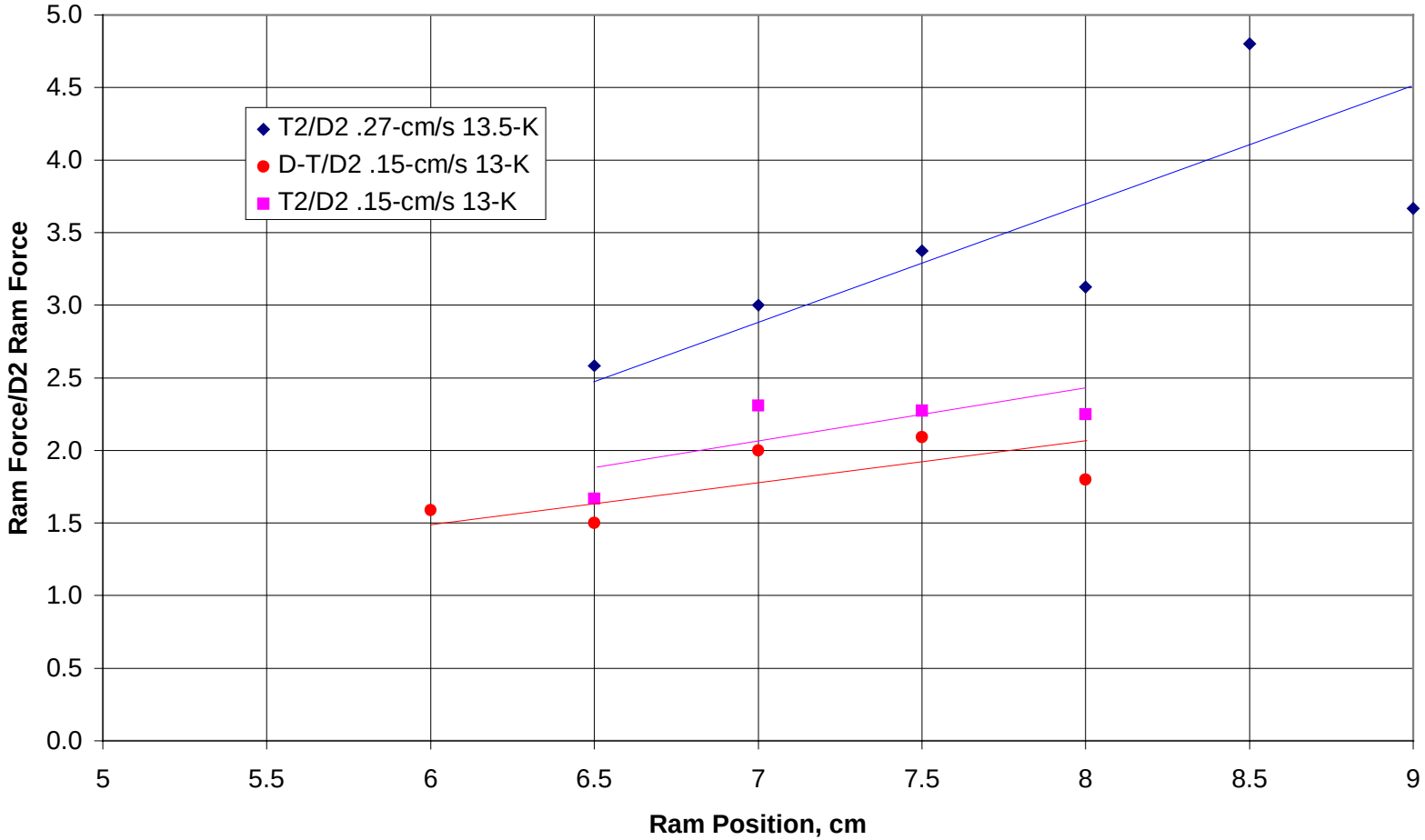
T_2 Extrusion



Shot	Material	Ram Speed, cm/s	TE2, K
1088	D_2	0.27	13.5
1155	T_2	0.27	13.5

At the same ram speed and temperature tritium requires more force than deuterium

Relative extrusion forces of T_2 and D-T with respect to D_2 at several conditions



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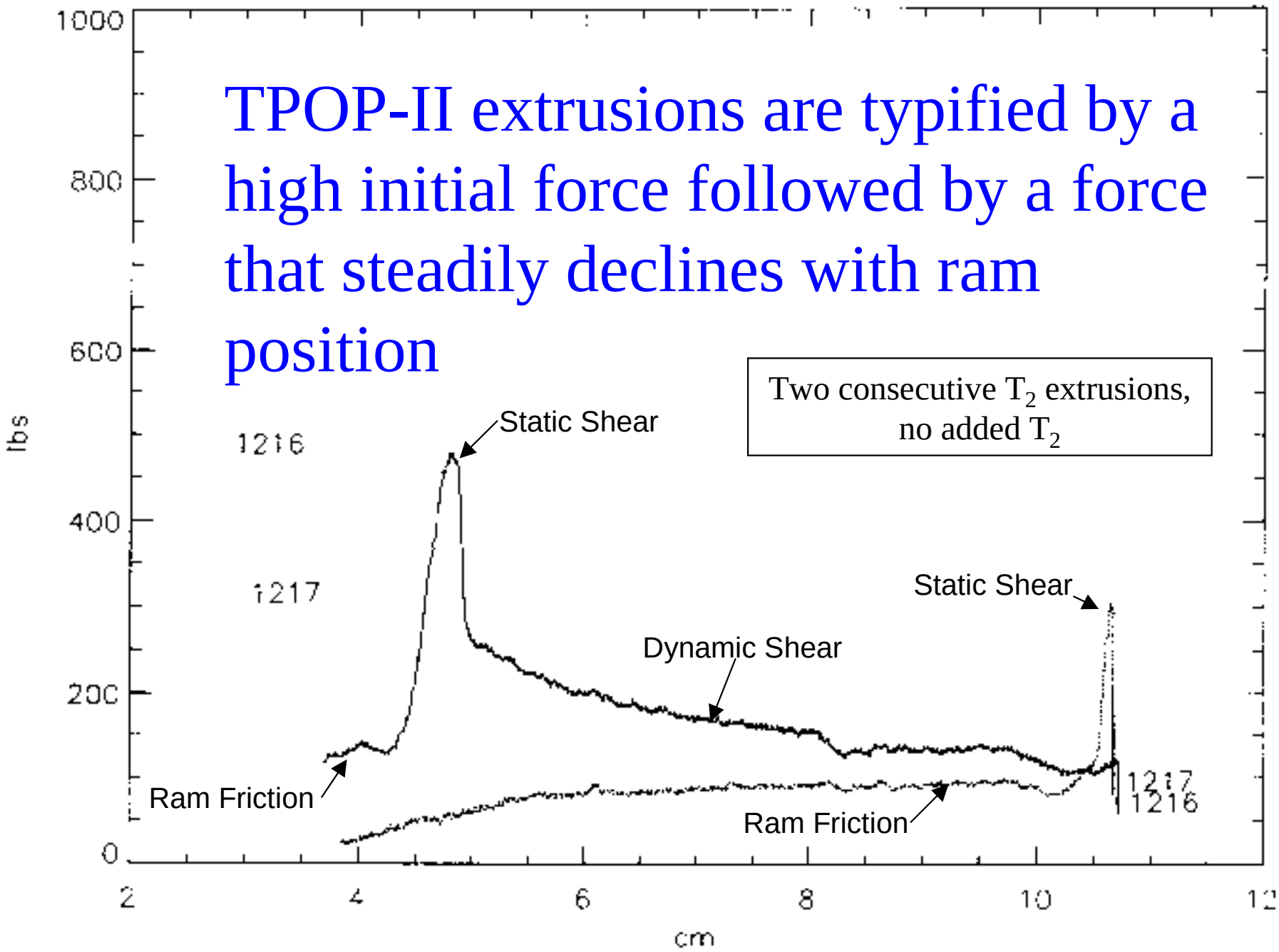
TPOP-II extrusions are typified by a high initial force followed by a force that steadily declines with ram position



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TPOP-II Static Shear Strength σ of Solid Hydrogen Isotopes

$$f(T,L) = f(Ram) + LP\sigma(T)$$

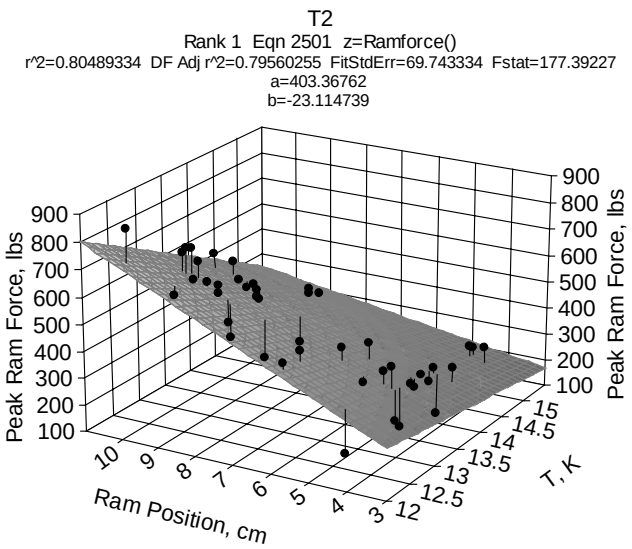
$$\sigma(T) = a+bT$$

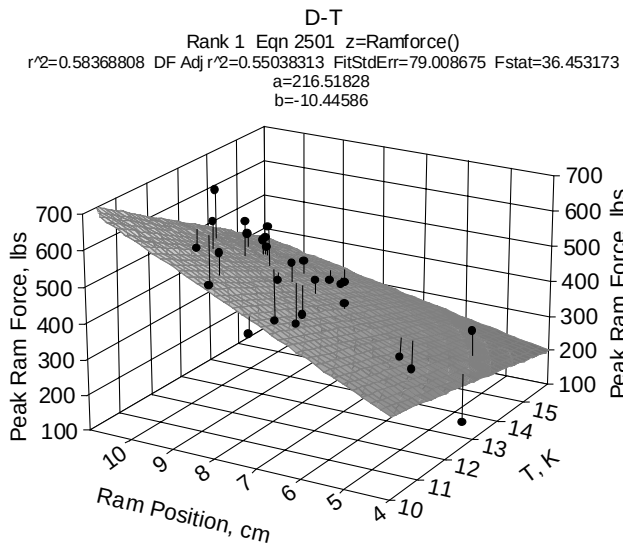
f(T,L) = Peak extrusion force

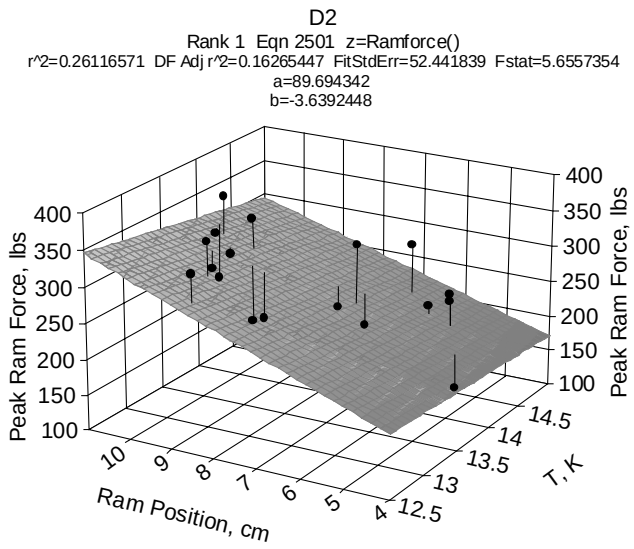
f(Ram) = Ram frictional force

L = Length of billet in extruder

P = Extruder perimeter







Isotope	Temperature Range, K	a, psi	b, psi/K	a, MPa	b, psi/K
D_2	13 – 15	89.7	-3.6	0.62	-0.025
D-T	12 – 15	216	-10.4	1.49	-0.072
T_2	12 – 15	403	-23.1	2.78	-0.159

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TPOP-II Dynamic Shear Strength σ_D of Solid Hydrogen Isotopes

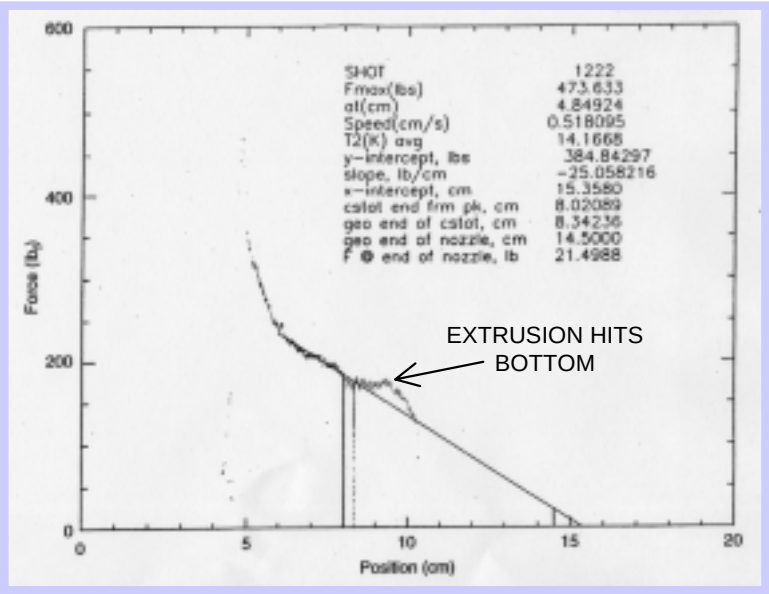
$$f(L) = f(Ram) + LP\sigma_D$$

f(L) = Extrusion force

f(Ram) = Ram frictional force

L = Length of billet in extruder

P = Extruder perimeter



Isotope	Temperature, K	σ_D, MPa	σ_D / σ
D_2	14	0.194	0.72
D-T	14	0.259	0.56
T_2	14	0.308	0.53

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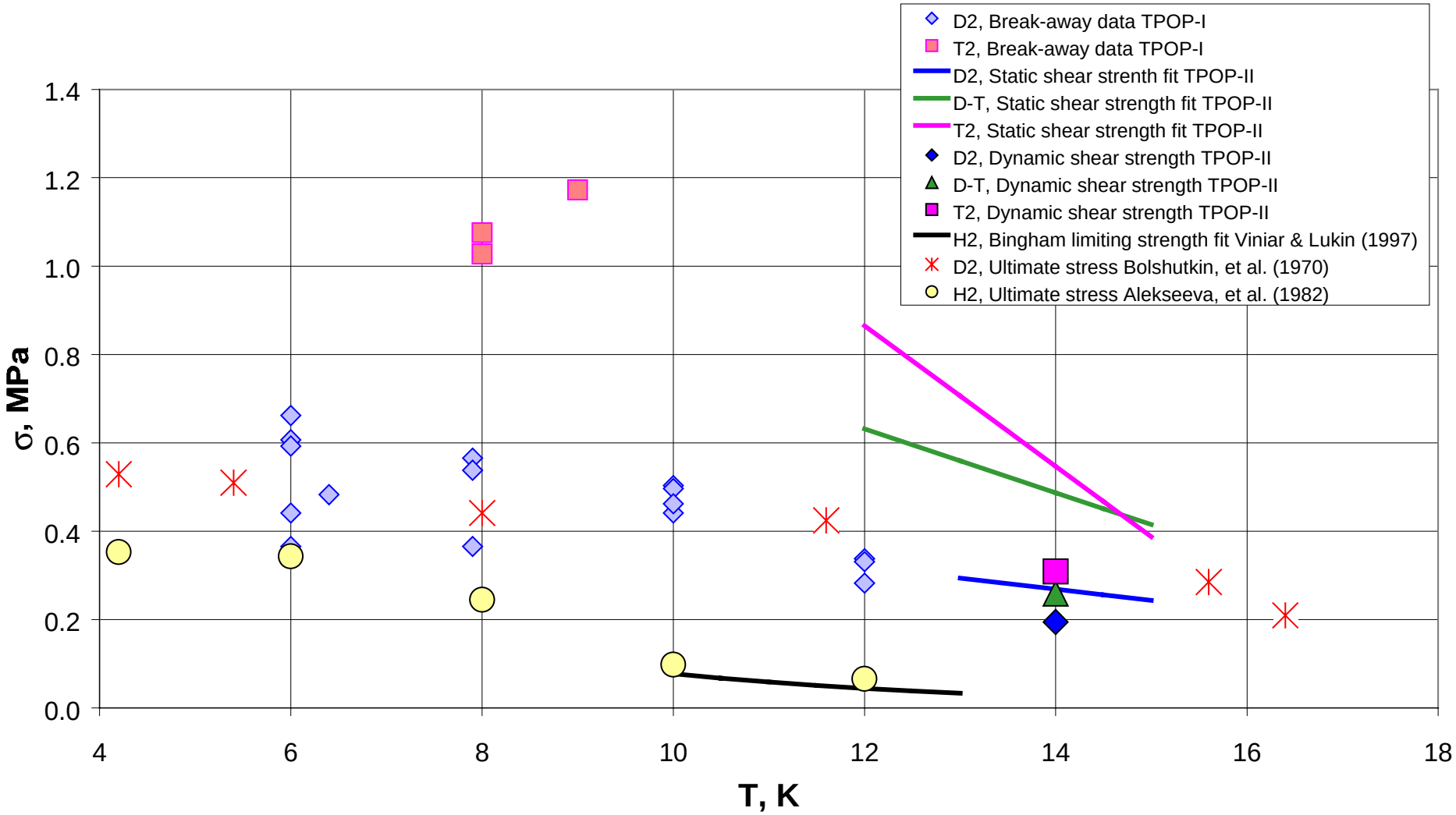
Strength of Solid Hydrogen Isotopes



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TPOP Summary

- About 38 g (380,000 Ci) of tritium were utilized in the experiment without incident
- Established the feasibility of production and pneumatic acceleration of tritium and D-T pellets for fueling future fusion reactors
  - 4 mm pipe gun pellets
    - H_2 to 1950 m/s; D_2 to 1800 m/s; D-T and T_2 to 1350 m/s
    - Velocities predicted well by interior ballistics
    - Predicted equilibrium pellet size
    - Calculated shear strengths from breakaway pressure data
    - >30 min delay to firing possible
  - 8 mm extruder-based repeating pneumatic injector (RPI) pellets
    - 0.5 Hz demonstrated with D_2
    - T_2 extruded at 1 Hz rate
    - Calculated static and dynamic shear strengths from extrusion force data
- Demonstrated cryogenic purification of tritium to <0.005% ^{3}He
  - Established an upper limit for pipe gun pellets of 0.005% ^{3}He
  - Established the feasibility of extruding tritium with 1% ^{3}He

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