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Advances in Hydrogen Isotope Separation Using Thermal Cycling Absorption Process (TCAP)

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Hydrogen Isotope Separation Timeline

- **Discovery of deuterium** **1931**
- **Discovery of tritium** **1934**
- **Isotope separation in SRS**
  - –Thermal diffusion **1957-1986**
  - –Fractional absorption **1964-1968**
  - –Batch Cryogenic distillation **1967-2004**
  - –TCAP **1994-present**

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TCAP Advance Continues

TCAP concept invented at SRL	1980
Experimental TCAP achieved 97% purity (D_2, H_2)	1983
Prototype TCAP achieved 99% purity (D_2, H_2)	1989
Pilot TCAP demonstrated (production-configured)	1993
Production TCAP achieved target T_2/D_2 separation	1994
Compact TnT design tested at LANL	2001
Batch Cryogenic distillation column replaced by TCAP	2004
Comp.-free CTC concept developed	2006
Comp.-free CTC experiment reached 4,000 cycles	2009
Inverse Column achieved 2X+ capacity & higher purity	2009
Micro-TCAP (batch) for LLE	2013
Mini-TCAP for Shine Medical Technologies	2014
CTC-TCAP with inverse column for SRS Tritium plant	2014+

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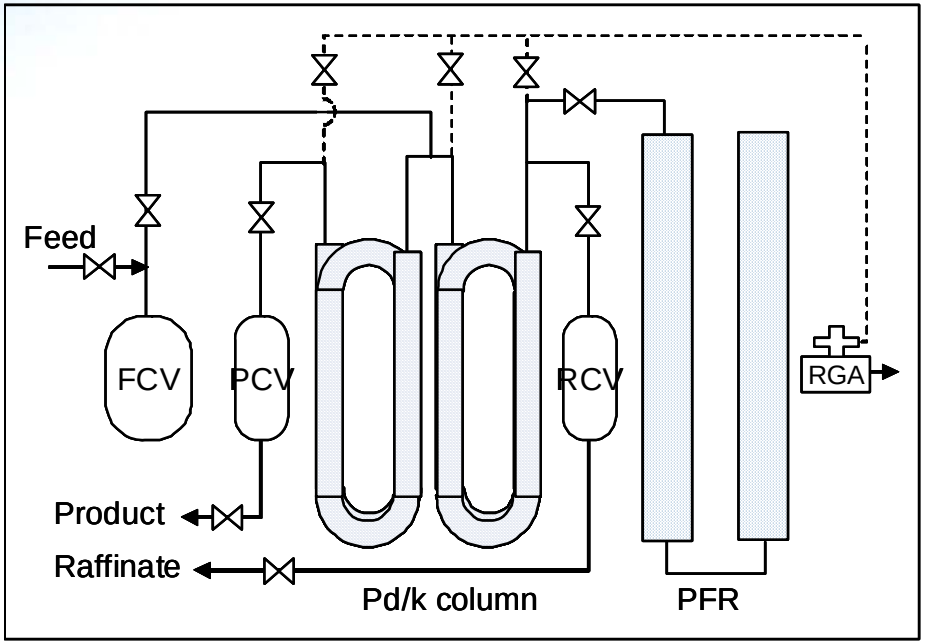
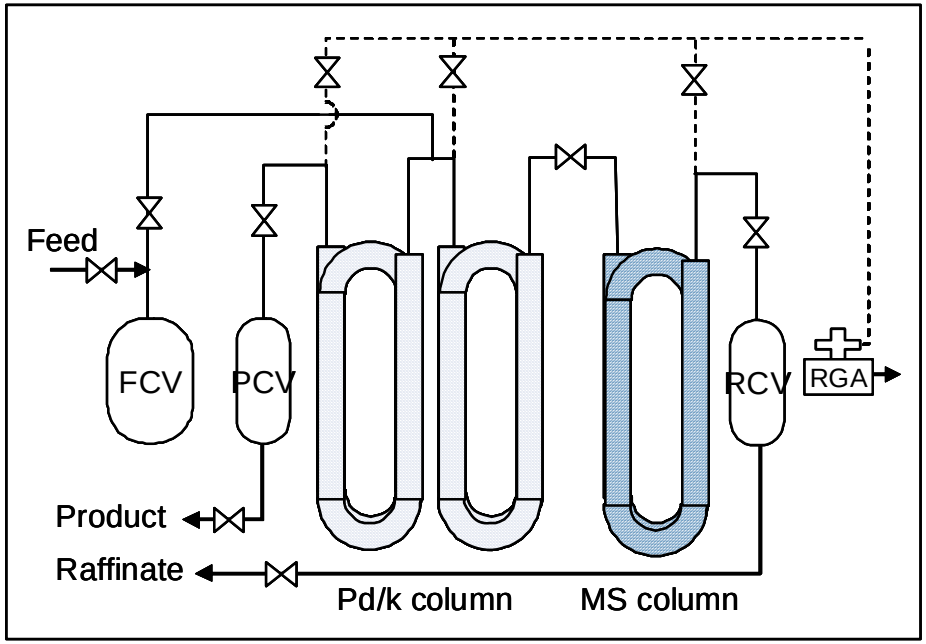
Advance 1: Inverse Column



Pd/k – PFR configuration



Pd/k – Inverse Column configuration

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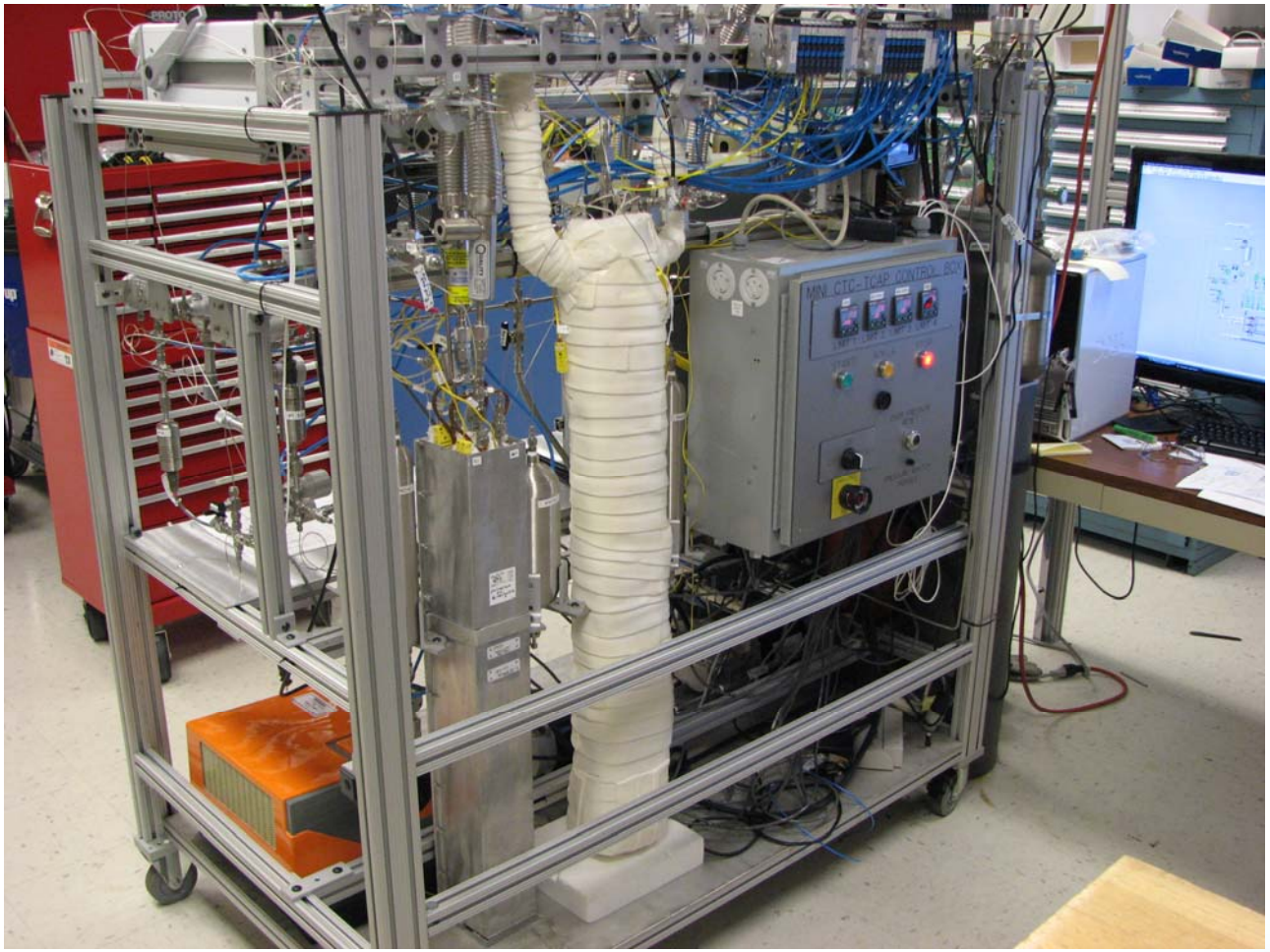
Mini-TCAP with Inverse Column Experimental Unit



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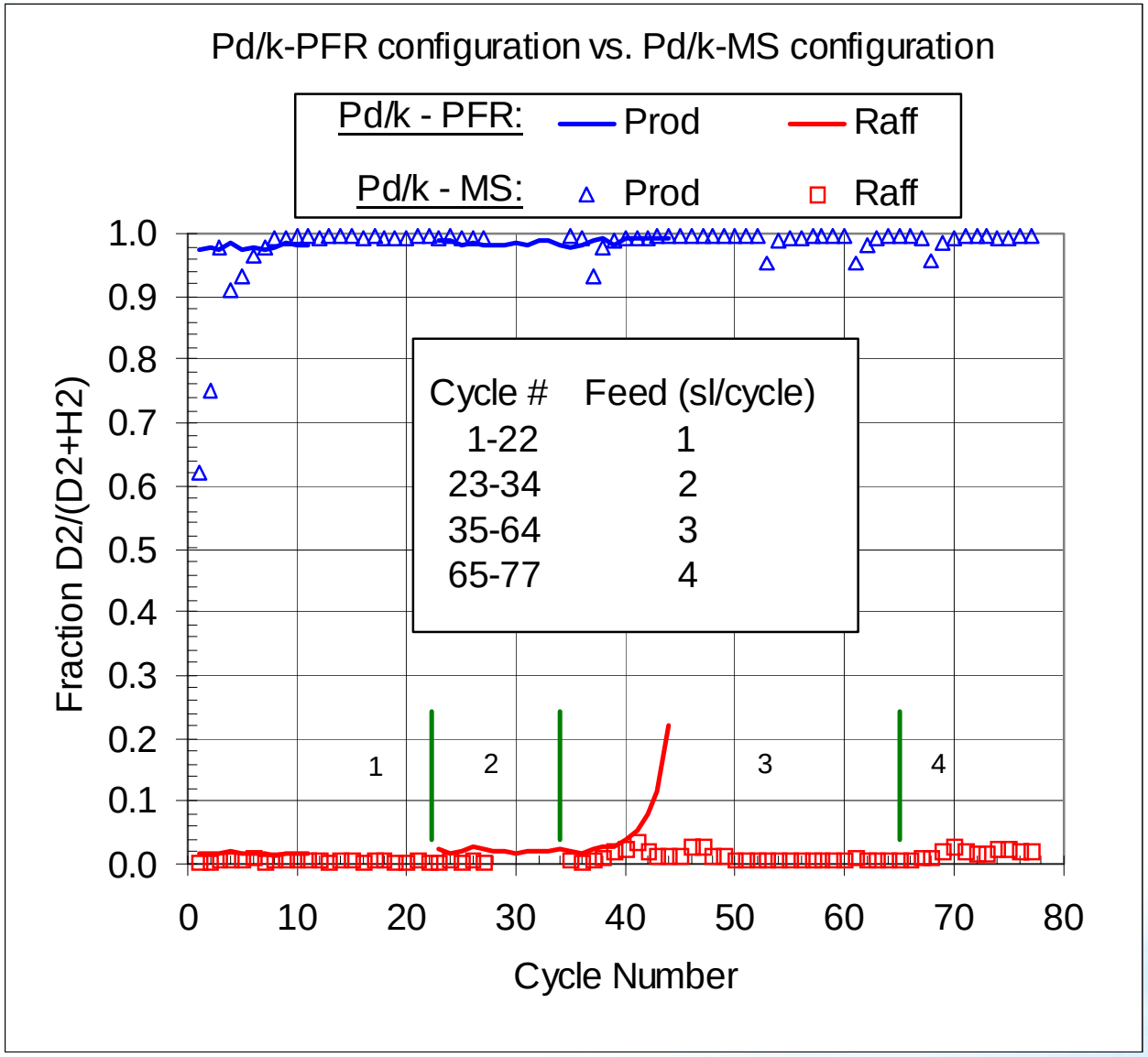
Throughput Doubled!



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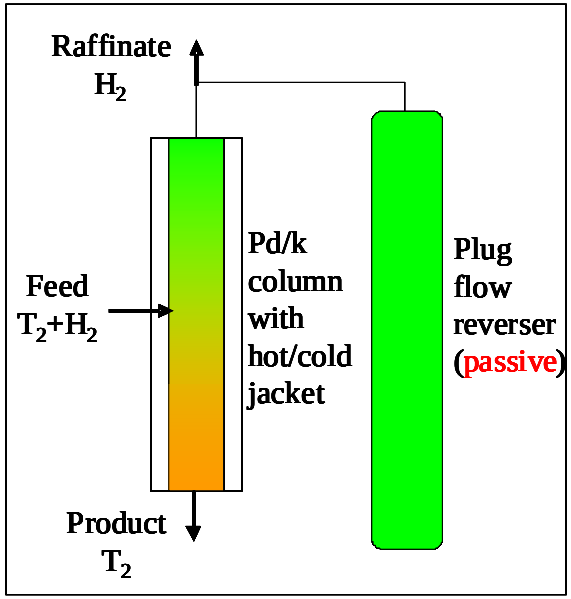
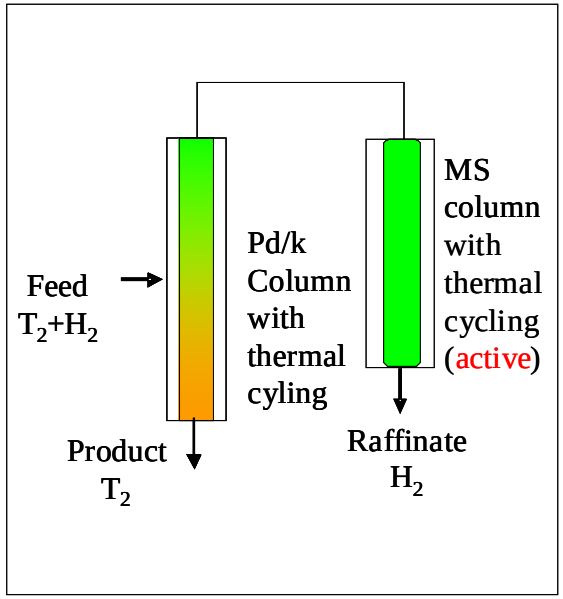
T_2 Inventory Reduction – to 1/2

Mini-TCAP Reduces T2 Inventory by ½ & possibly more

Present TCAP

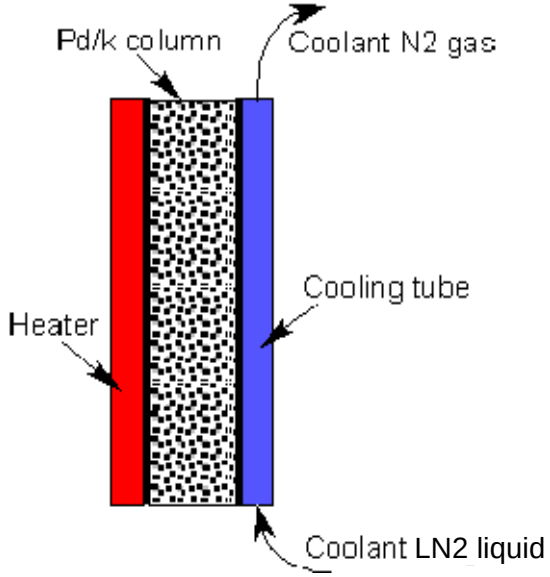


Advanced TCAP



Advance 2: Extremely Compact Column Design

Better heat transfer with counter-flow



Replacement of heater possible

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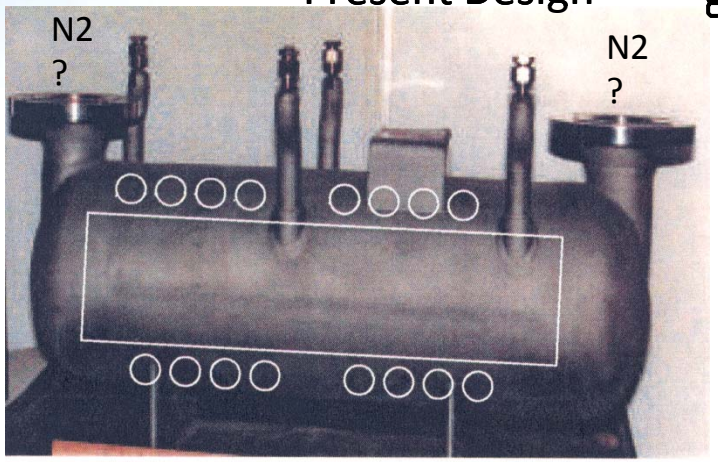
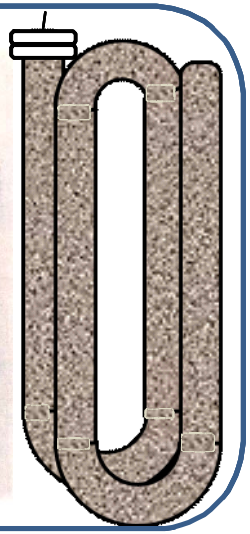
Heat Load Reduction – to 25%

Present Design





Mini Design

Components	Heat Load	
	Present Design	Mini Design
Total (relative)	100	25
Packing material	10 %	24 %
Column	16 %	38 %
Jacket/Cooling tube	74 %	38 %

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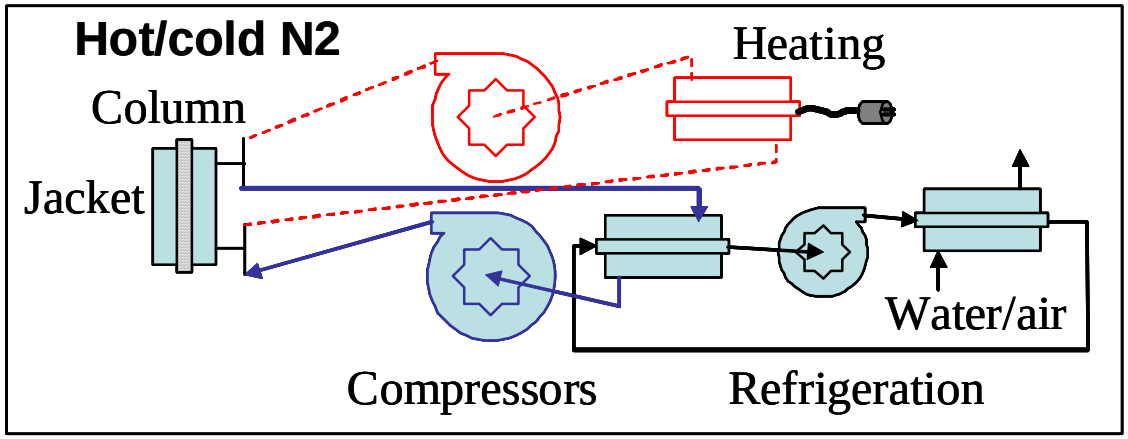
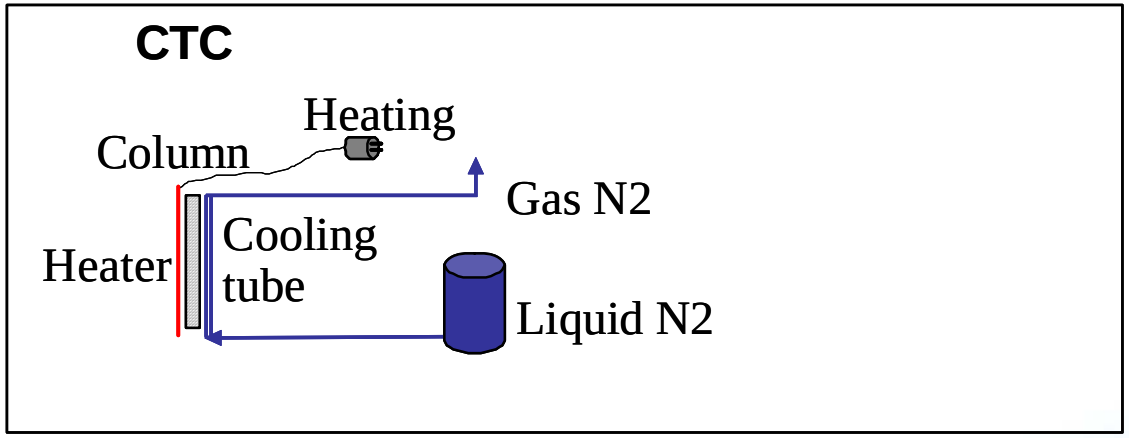
Advance 3: Equipment & Footprint Reduction to 1/10th

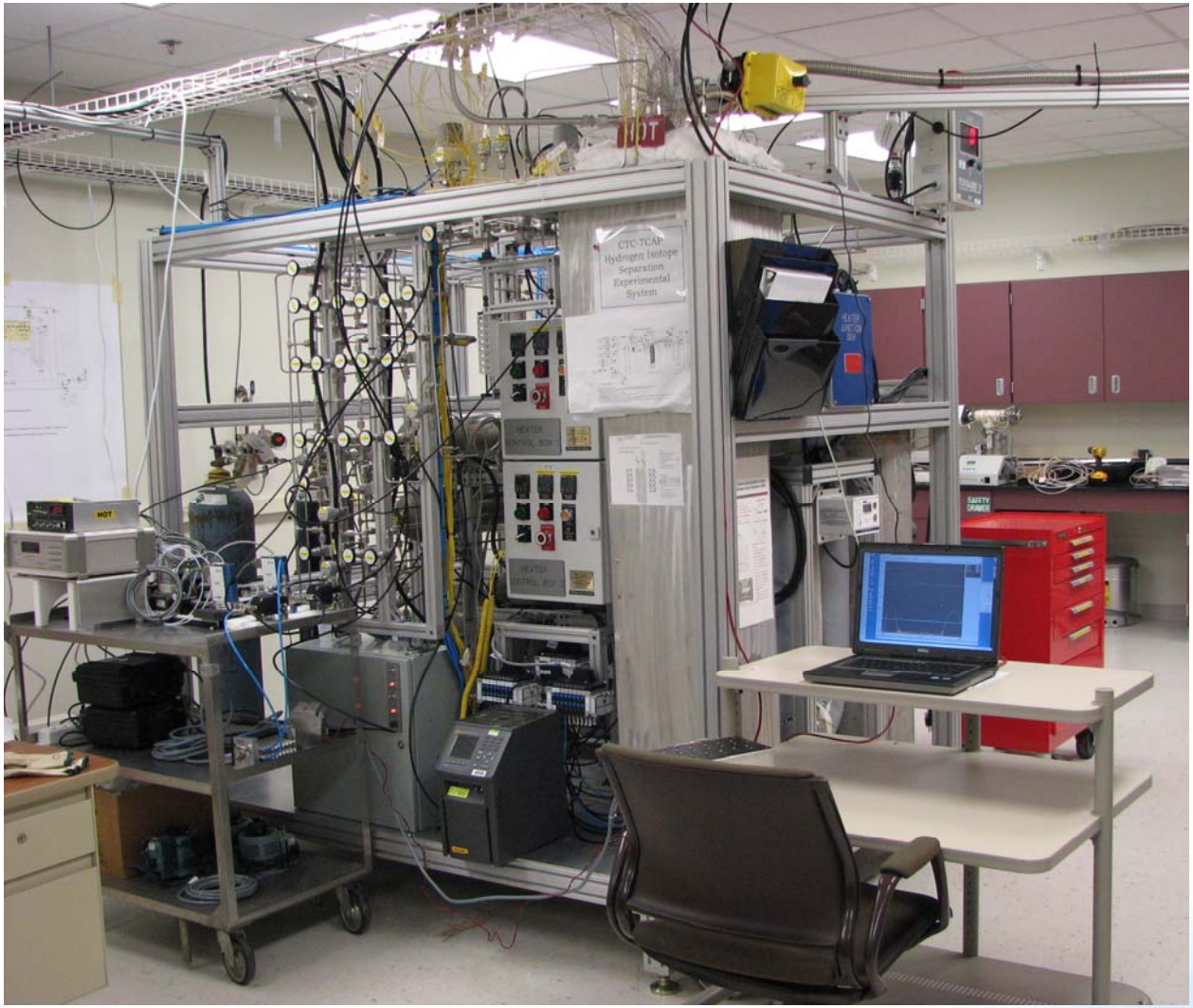
Present TCAP System



Compressor-free CTC-TCAP System



CTC-TCAP Experimental Unit



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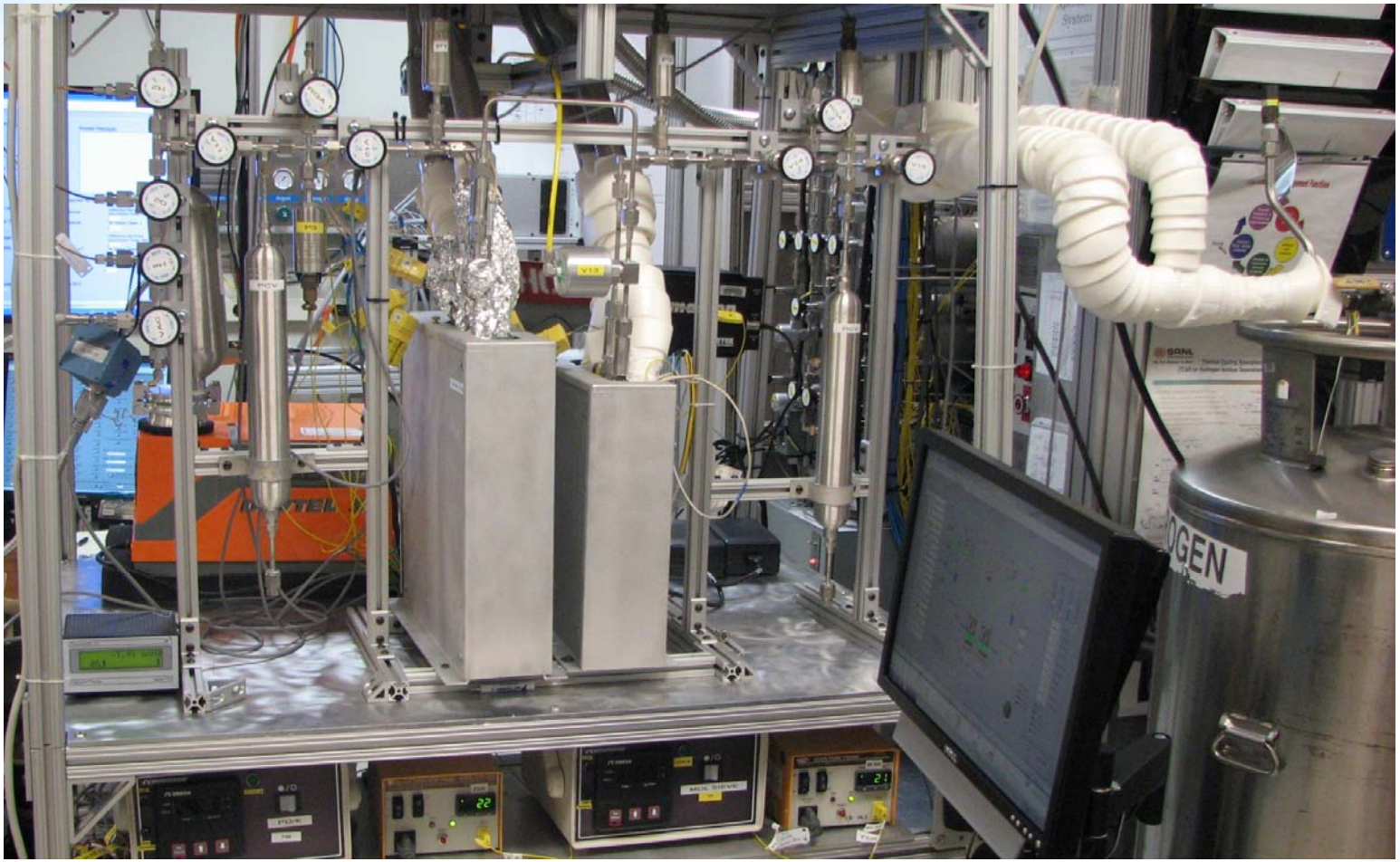
Advance 4: Micro-System Fits into a Small Glovebox



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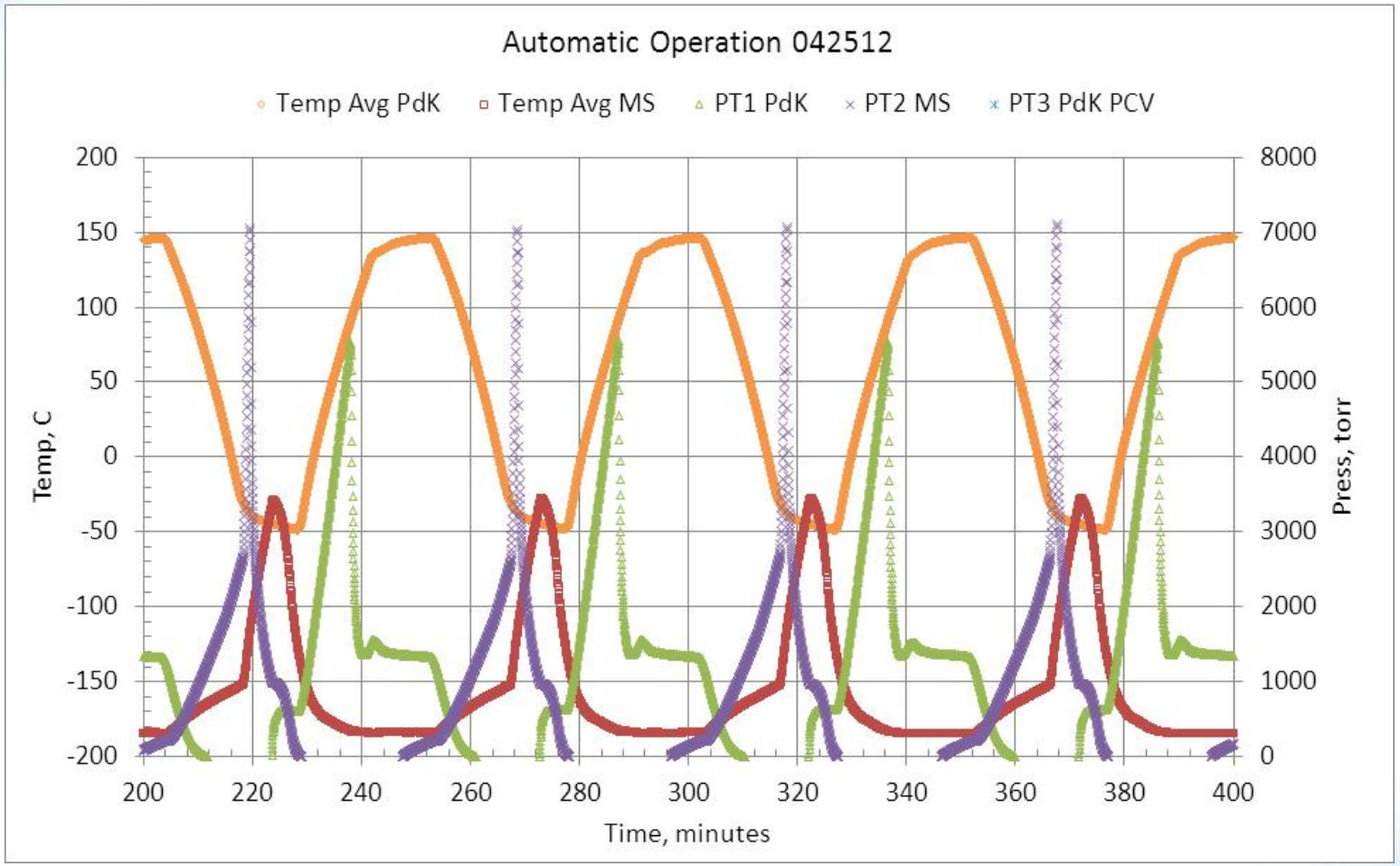
Micro-TCAP Typical T and P Cycles



Advance 5: Parameter Optimized with 50% Efforts

Test No.	**A** (inventory)	**B** (Delta P)	**AxB CxD**	**C** (hi press)	**AxC BxD**	**AxD BxC**	**D** (gas to middle)
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Experimental Design via Taguchi's methods: orthogonal arrays

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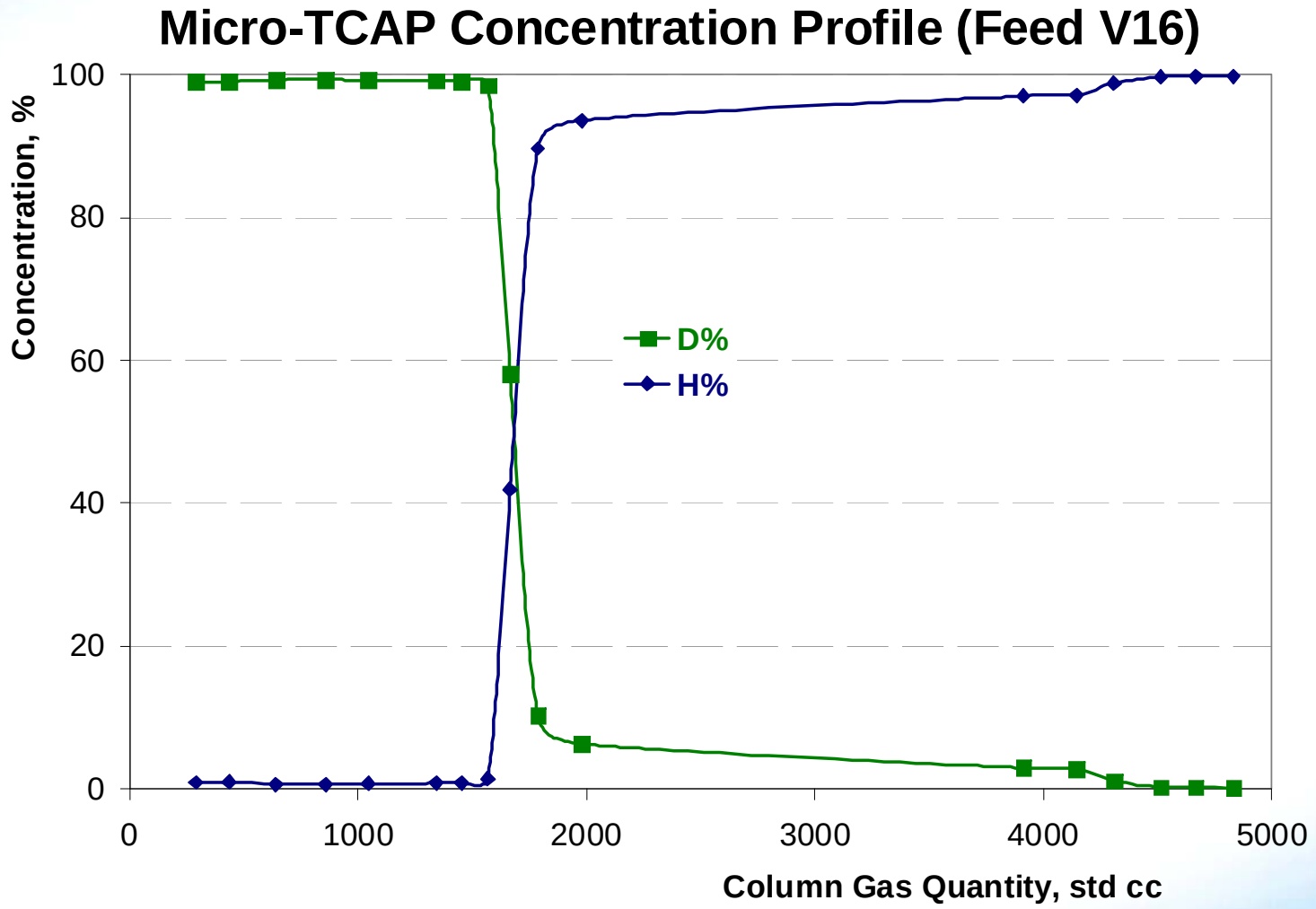
Reduced Cycles from 20 To 10



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Summary of Benefits

- **Double throughput;**
- **Reduction of tritium inventory to 1/2;**
- **Reduction of heat load to 25%;**
- **Footprint Reduction to 1/10th;**
- **Miniature version fit into a small glovebox;**
- **Reduced workload by implementing Experimental Design – potential incentive in other tritium work.**

Collaboration with Dr. Walter T. Shmayda – Laboratory for Laser Energetics, University of Rochester, for Micro-TCAP development is acknowledged.

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