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The Development of LITER - a Lithium Evaporator for Use in Fusion Devices

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48th APS – DPP Meeting
Oct. 30-Nov. 3, 2006
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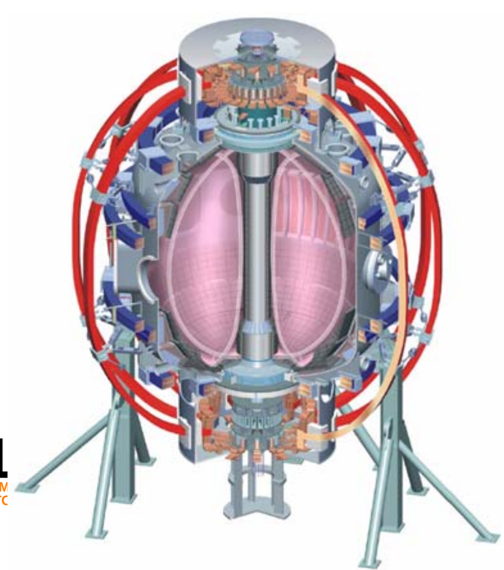


Abstract

An evaporator to be used for the deposition of elemental lithium onto the plasma facing components of fusion devices has undergone several stages of design, evaluation and development. A ~150 Watt prototype evaporator with a modest 10 gram reservoir was first tested in the laboratory before it was successfully employed on the CDX-U device in a horizontally-pointing geometry. Drawing on that experience, the prototype evaporator design then evolved through several stages as its reservoir capacity was increased to 50 - 100 grams, its power consumption increased to ~ 300 Watts and its pointing-orientation changed from horizontal to vertically-downward so that it could be used to coat the lower divertor in the NSTX device. These design changes were dictated from both laboratory experience and from practical experience on NSTX. The most challenging problems associated with the evaporator have been the need to achieve reasonable rates of evaporation (1 - 100 mg/min) at operating temperatures in the range of 500 C - 700 C while avoiding the uncontrolled wetting (or spreading) of the lithium onto external regions of the evaporator. The design and performance of the evaporator at each stage of its development will be summarized and discussed in detail.

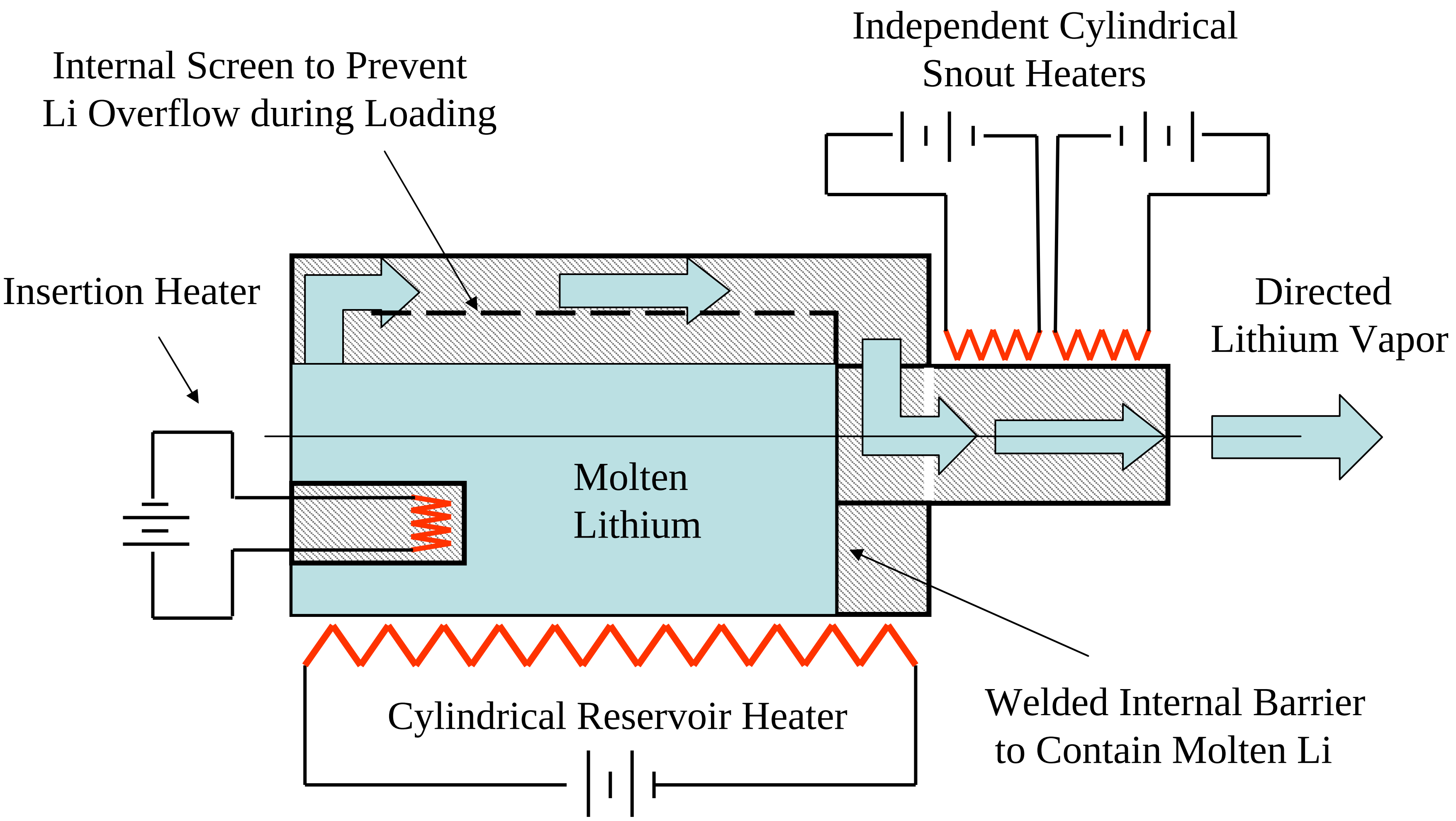
*Supported by DOE contract DE-AC02-76CH03073.

The First Attempt: Proto-LITER

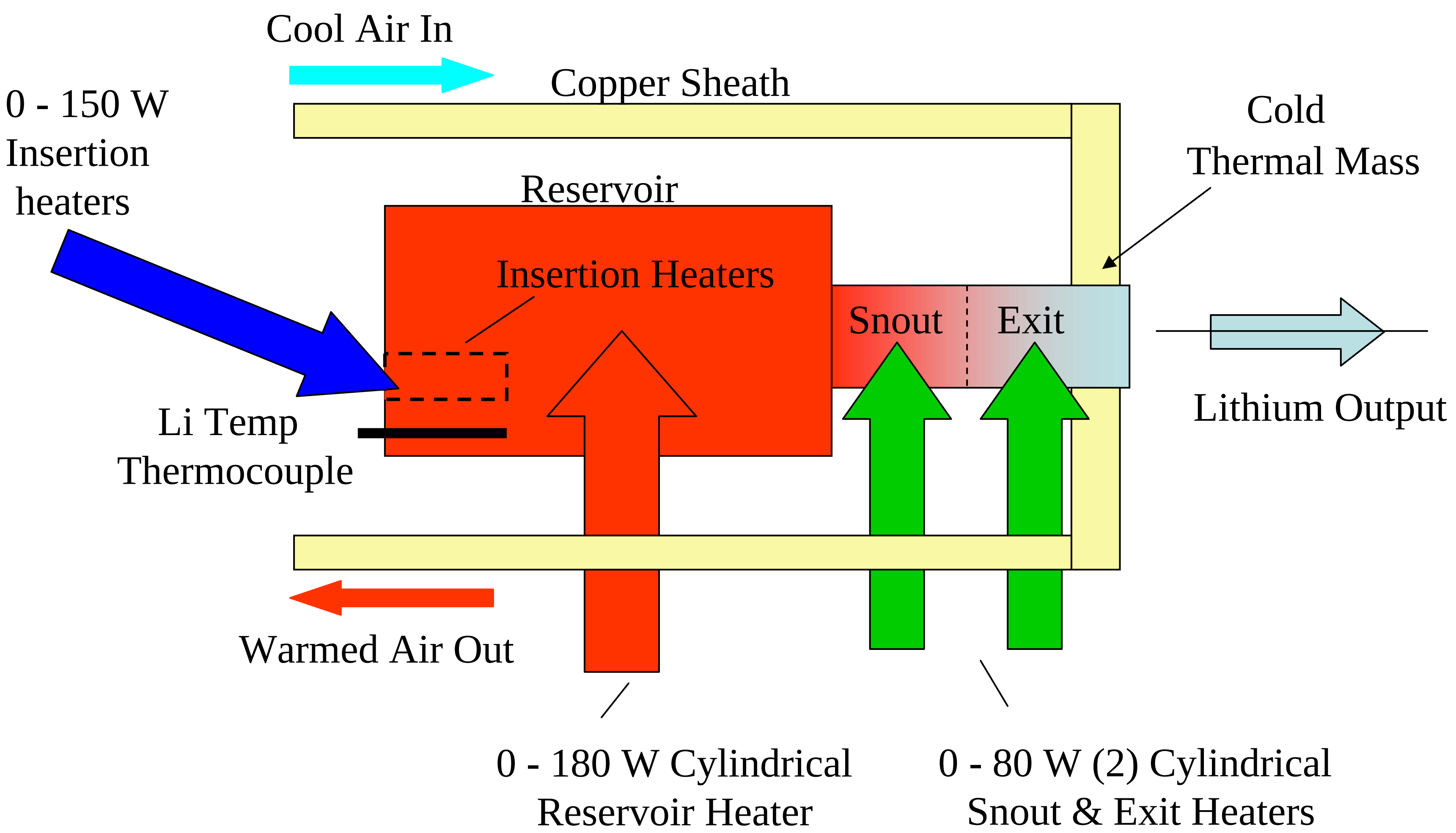
The first evaporator attempt was called Proto-LITER (LIThium EvaporatoR) and is discussed in panels 1-17.

- **Panels 4 - 6 display the mechanical design and heating / cooling scheme employed by the Proto-LITER device.**
- **Panel 7 displays the calculated deposition rate based on the device geometry and the known lithium pressure dependence on temperature.**
- **Panels 8 - 11 show the as-built prototype.**
- **Panel 12 displays the experimental set-up used to evaluate Proto-LITER.**
- **Panel 13 displays two modes of Proto-LITER operation that were tested while the results of those tests are shown in Panels 14, 15 and 16.**
- **Panel 17 shows how the lithium heat of fusion was exploited to yield a relative measurement of the remaining lithium inventory after an evaporation.**

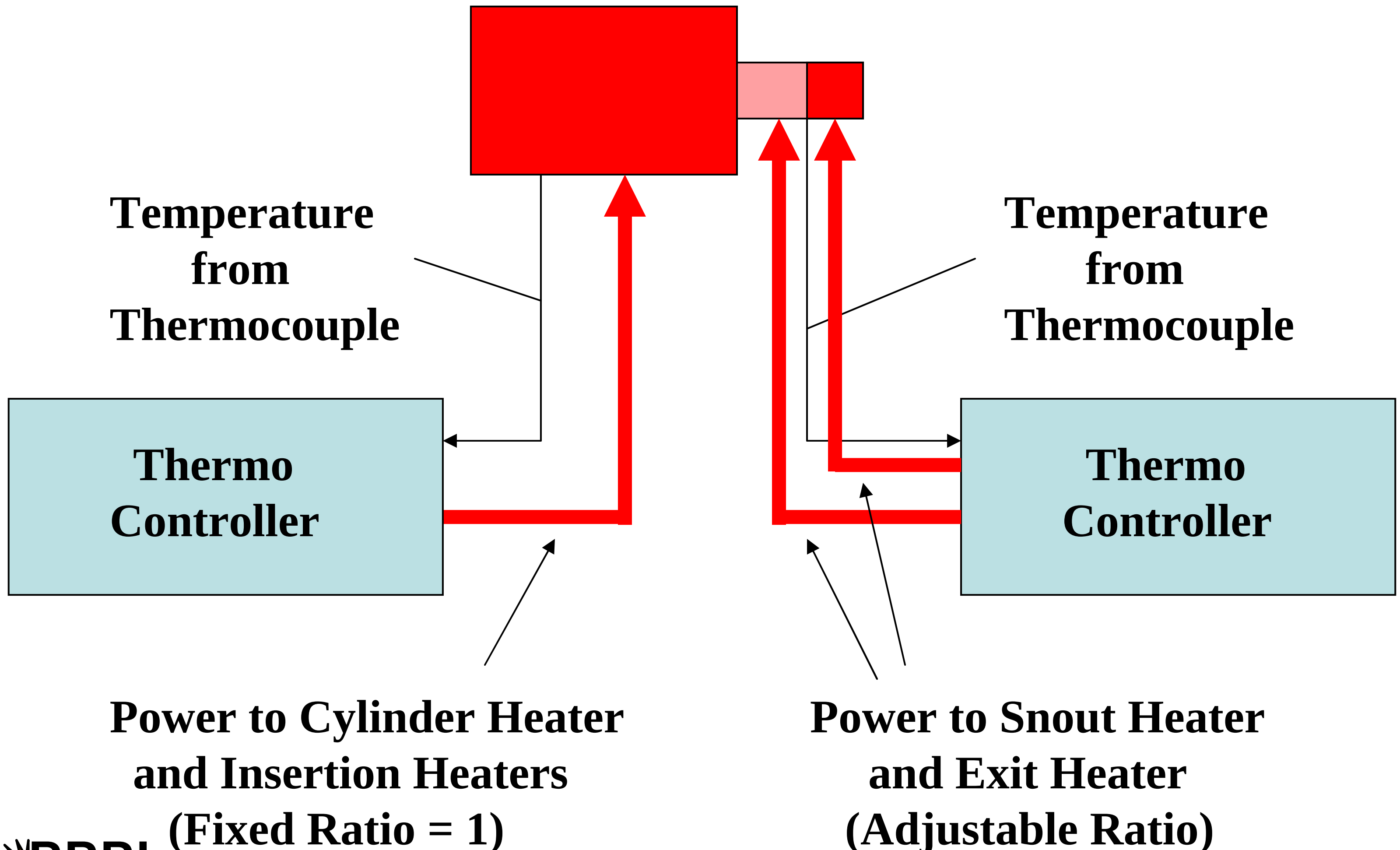
PPPL Proto-LITER Evaporator Geometry



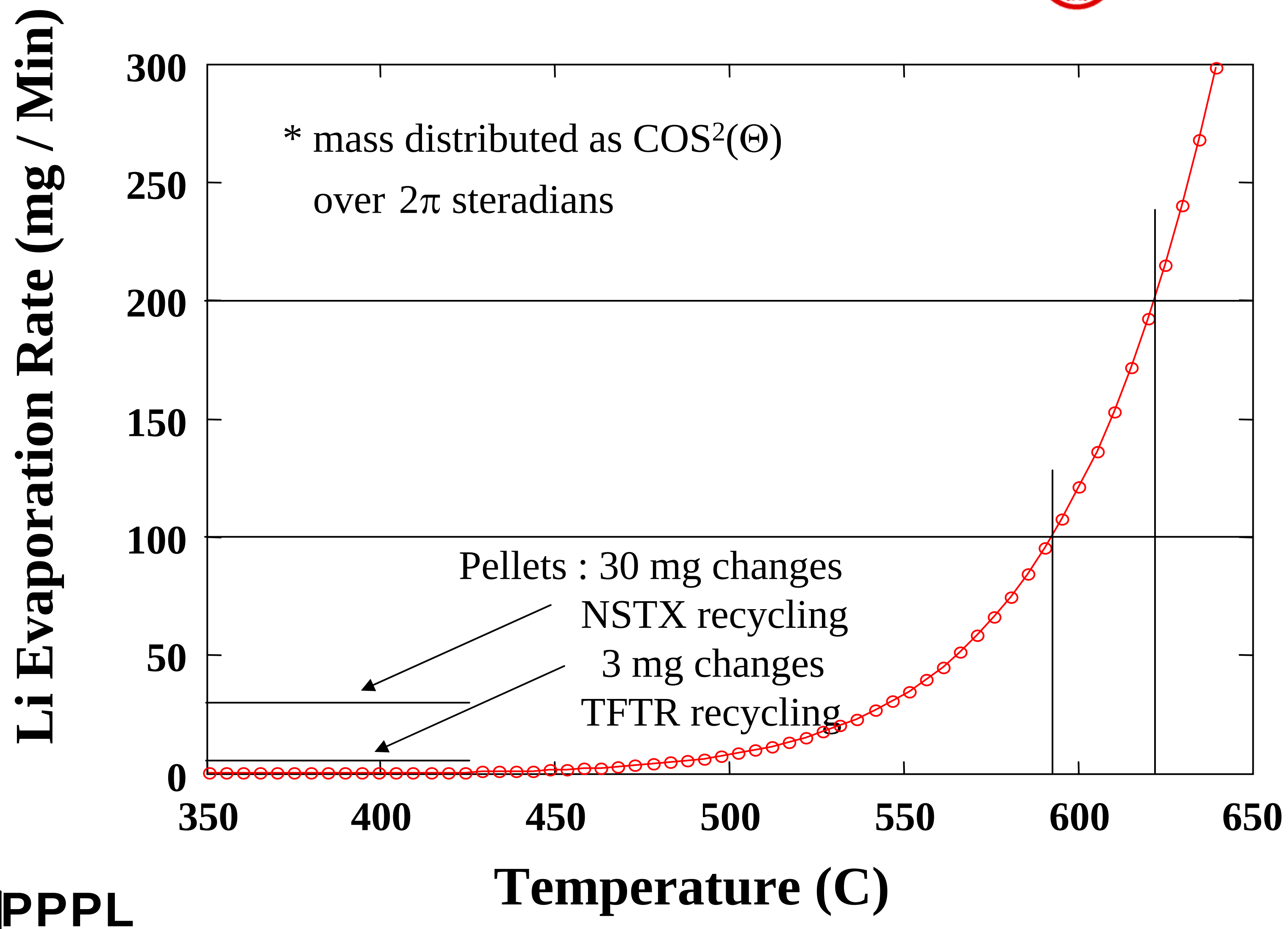
Proto-LITER Heating and Cooling



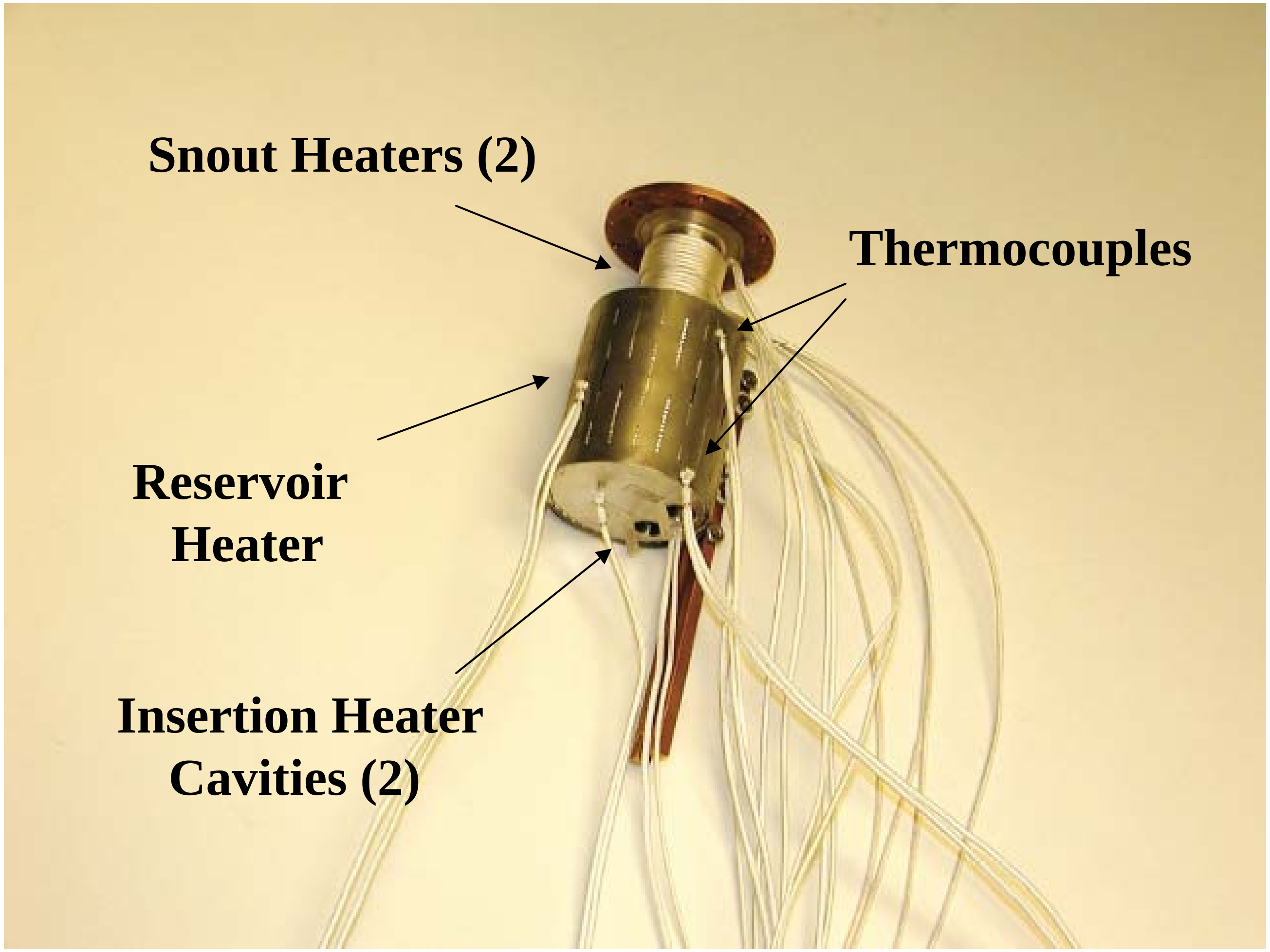
Proto-LITER Power Sharing Scheme



Proto-LITER Theoretical Evaporation Rate



Proto-LITER with Heaters and Thermocouples



Proto-LITER with Heat Shield

NSTX

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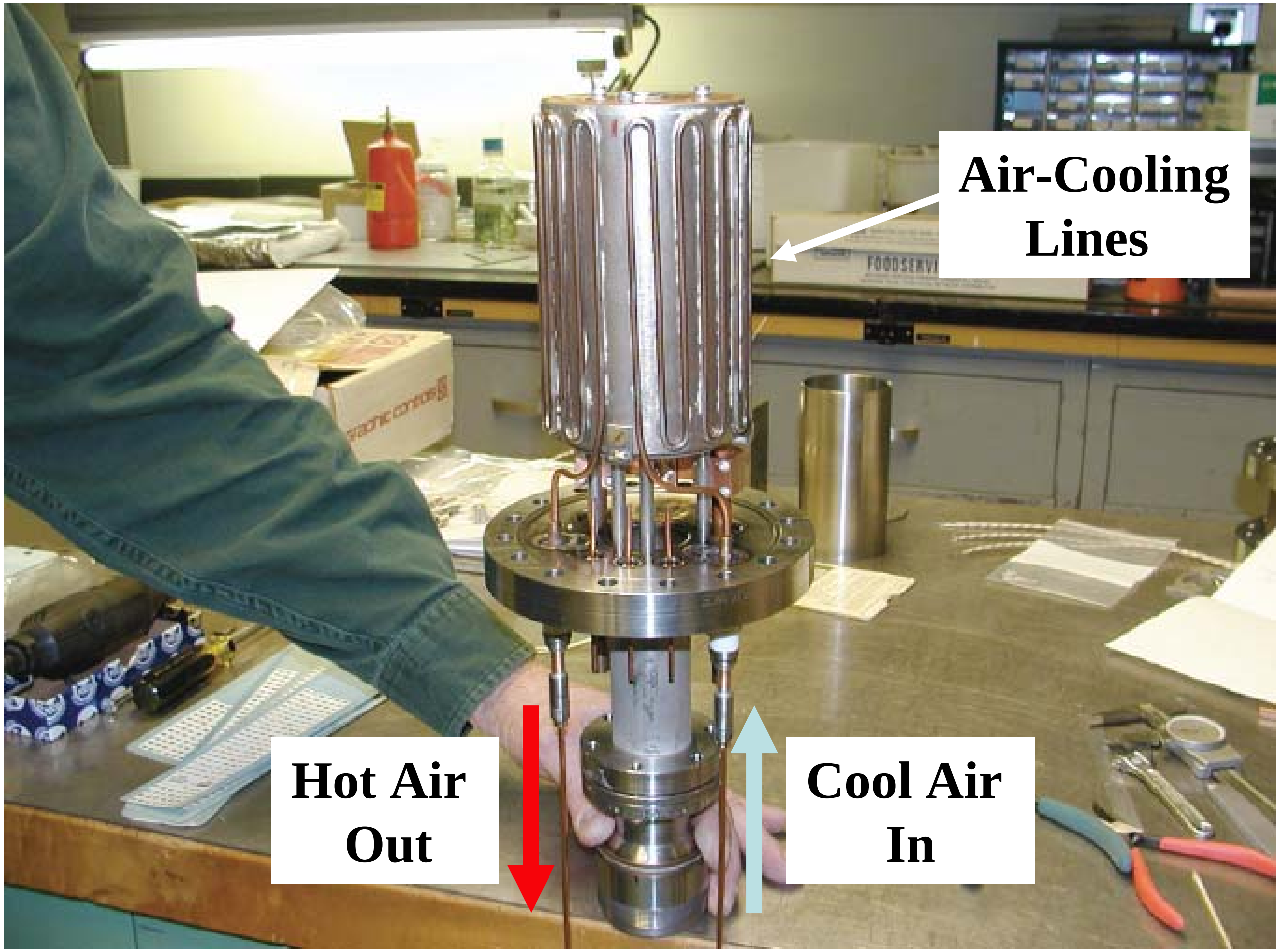
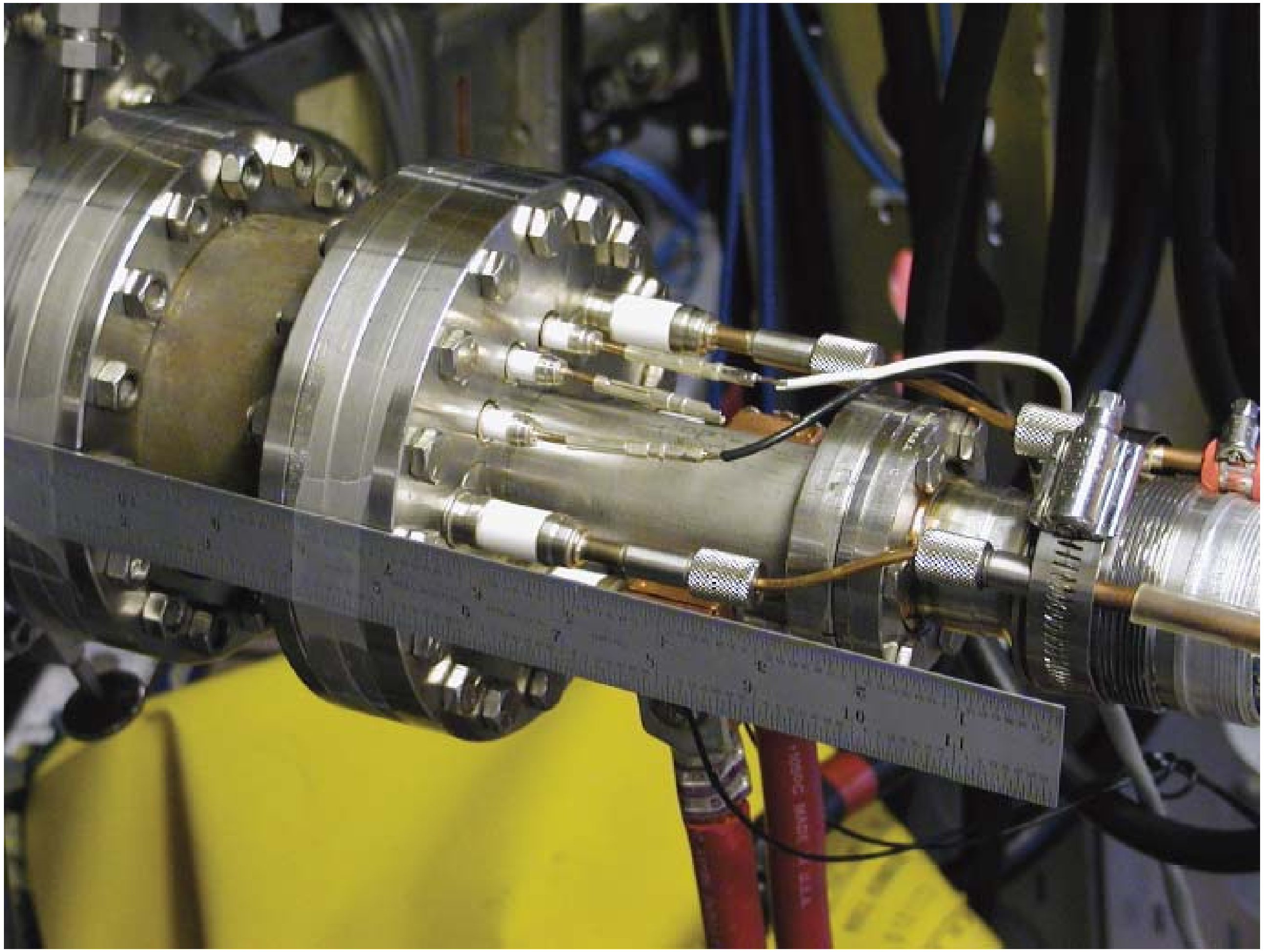
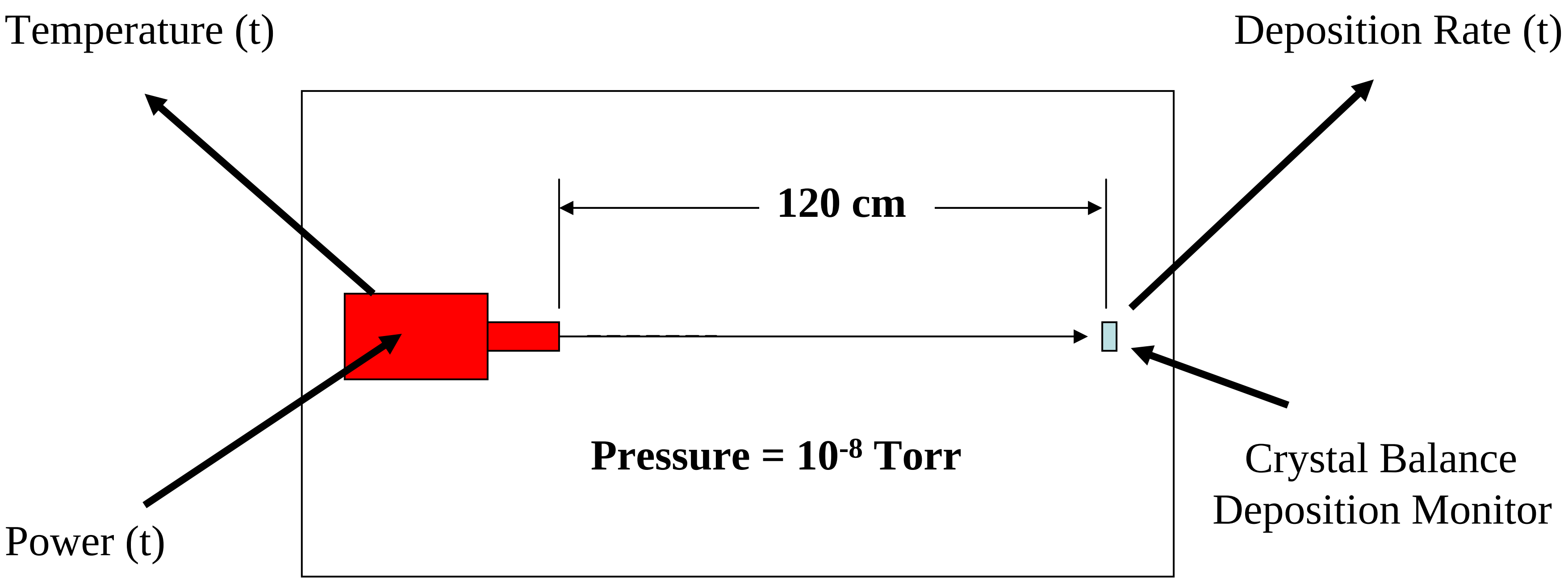
Proto-LITER with Air-Cooled Copper Shroud



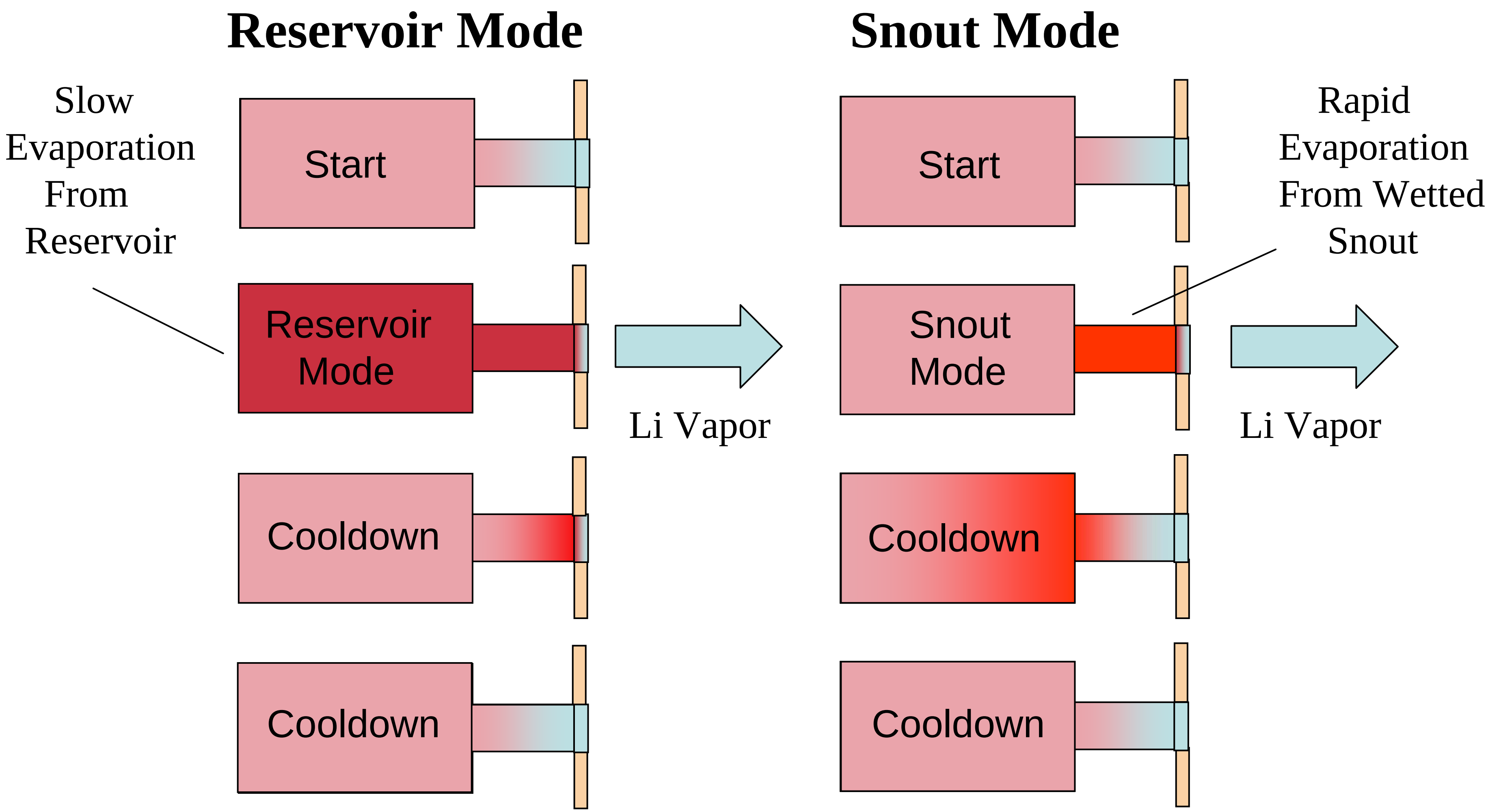
Proto-LITER as Installed Horizontally on CDX-U Experiment



Proto-LITER Test Geometry

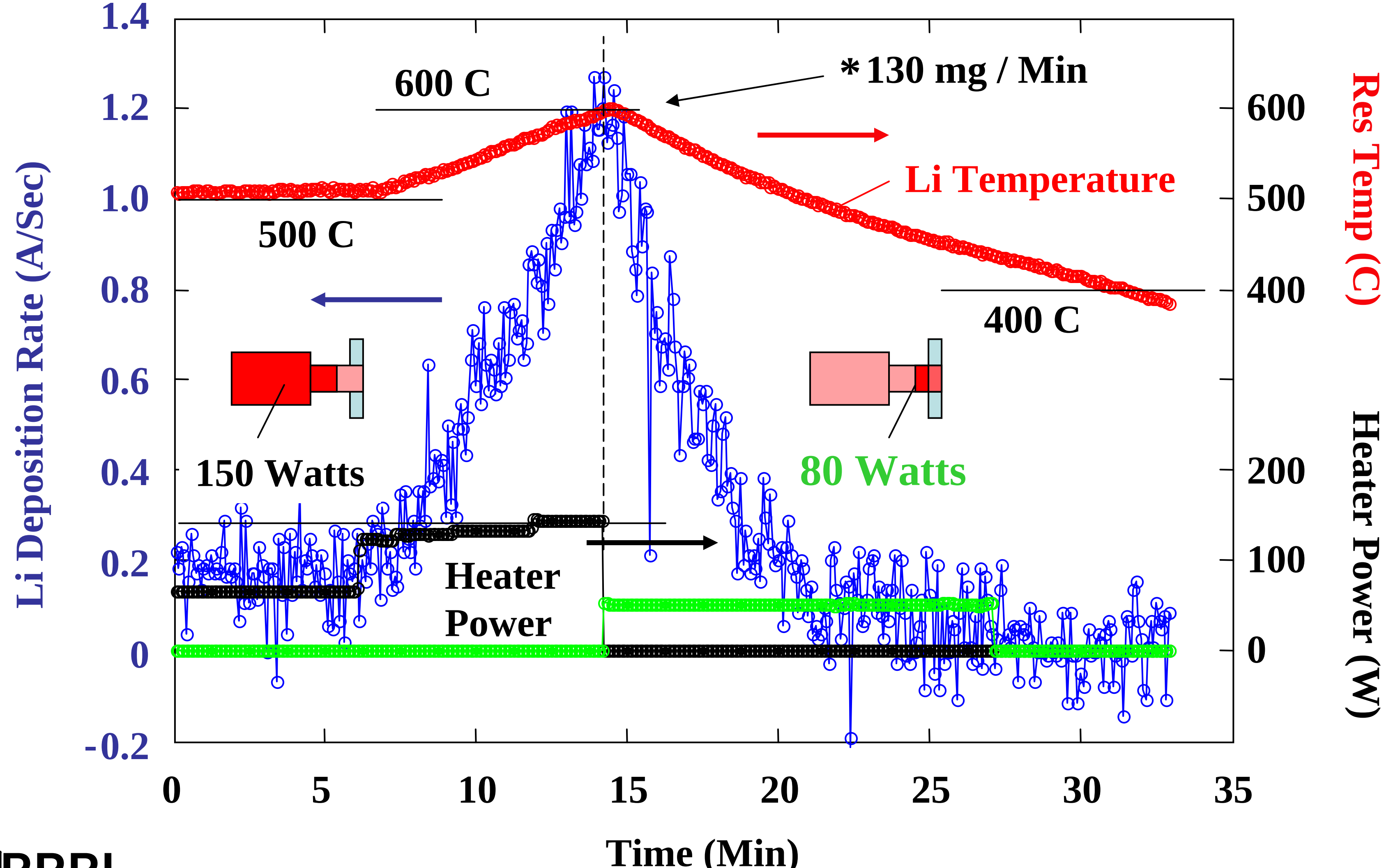


Proto-LITER: The Two Modes of Operation



Deposition Rate: Proto-LITER Operating in Reservoir Mode

NSTX



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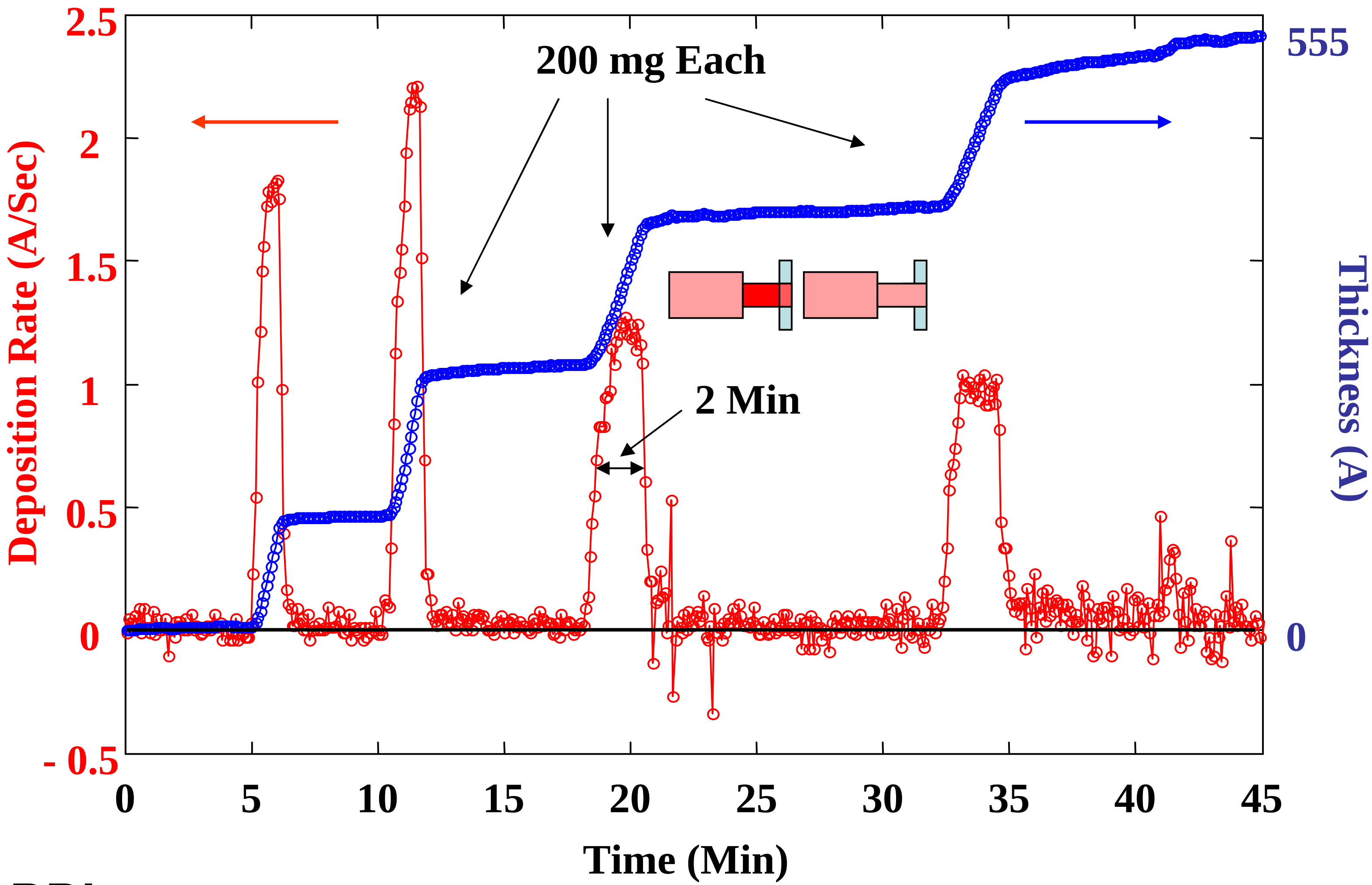
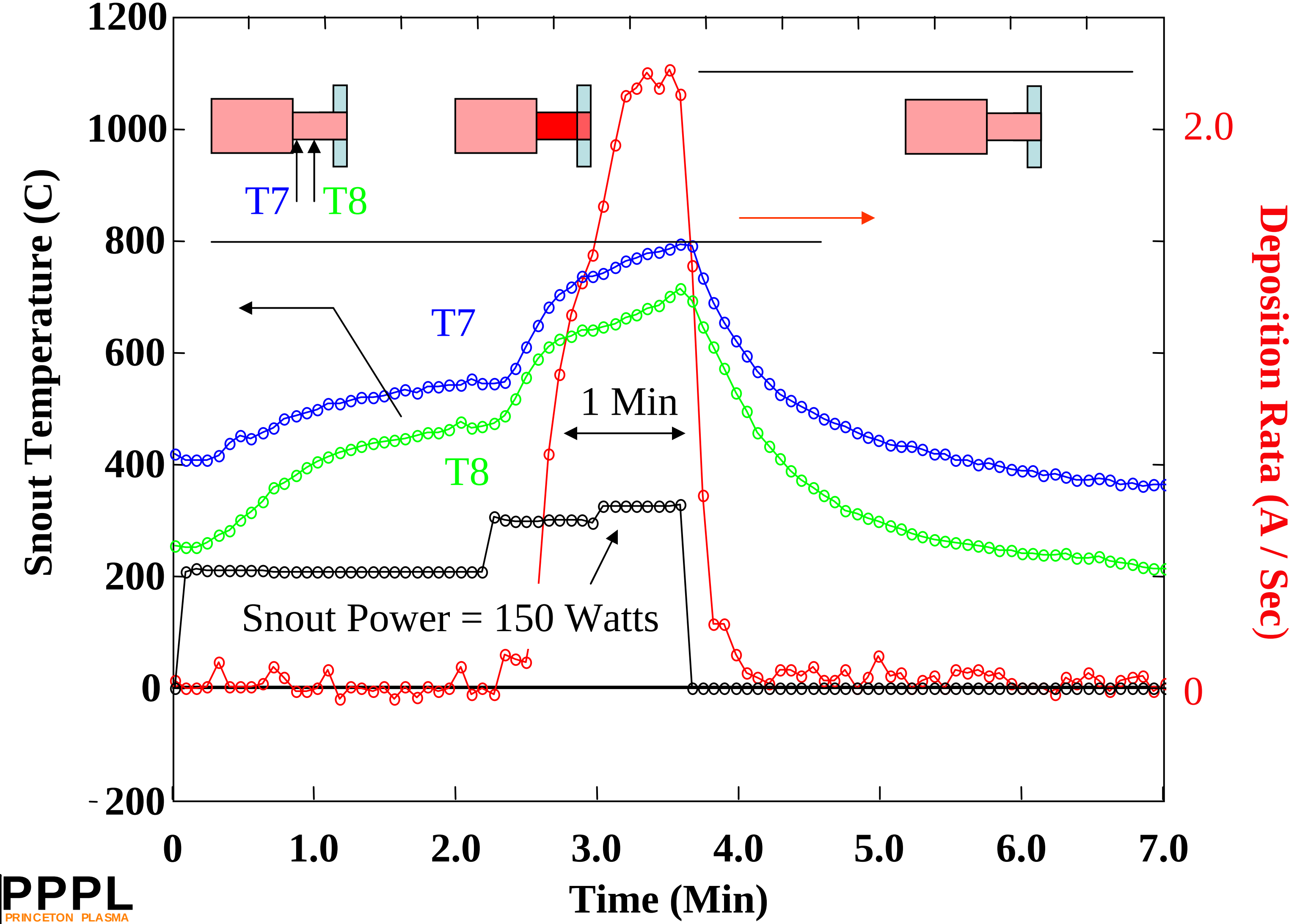
Deposition Rate: Proto-LITER Operating in Snout Mode



Snout Mode: Rapid Deposition (~ 800 C) and Cool-Down



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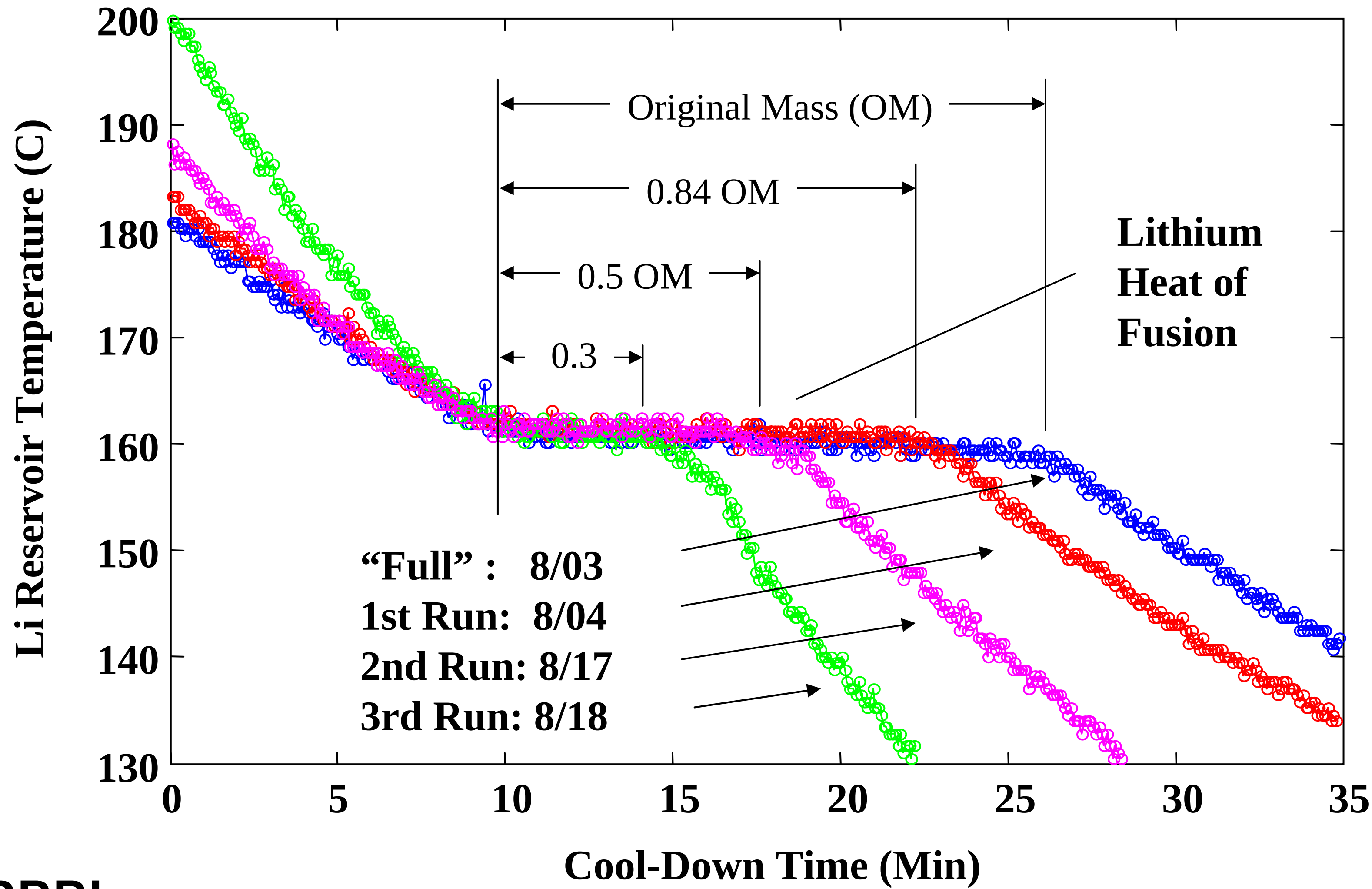
Depletion of Proto-LITER Reservoir During Three CDX Runs

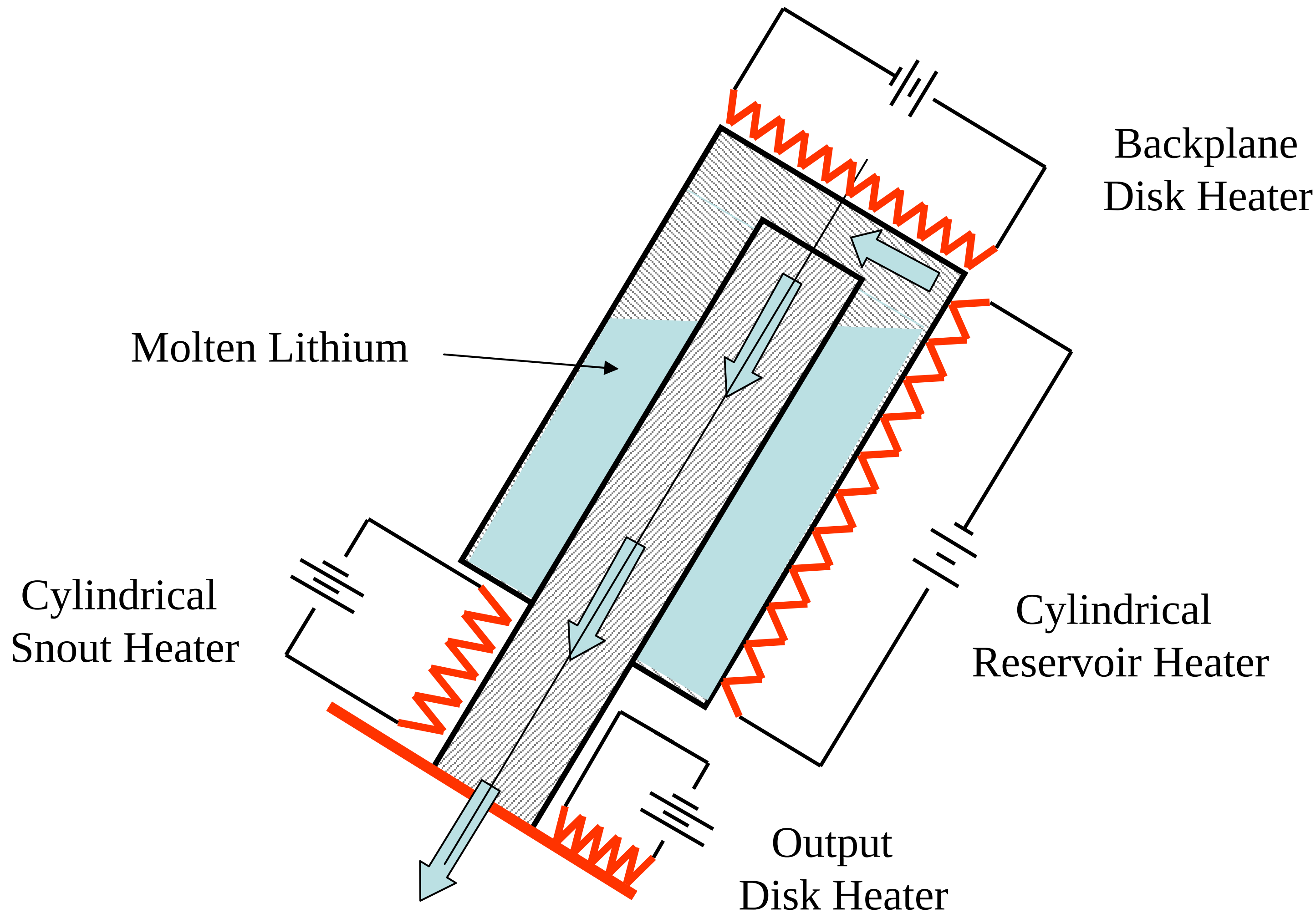


From Prototype to LITER on NSTX

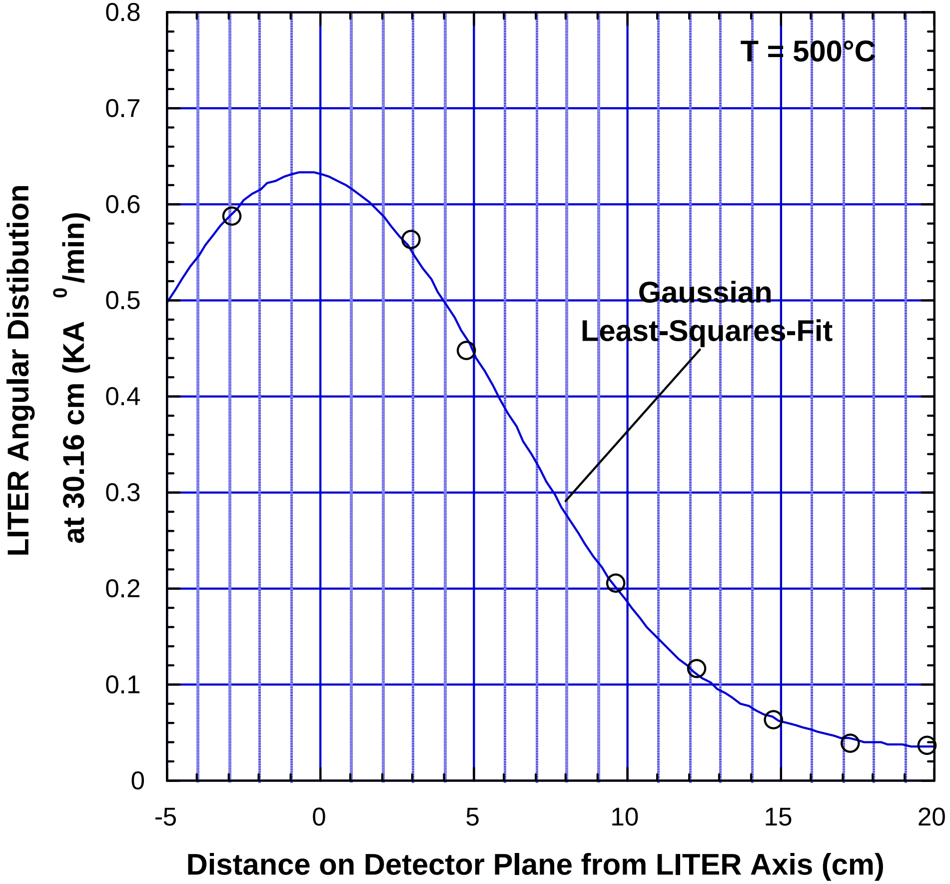
After using Proto-LITER on CDX-U successfully, the design was modified to generate a vertically-downward directed Li vapor. This fundamental change was made in order to coat the lower divertor region of NSTX. The development of the so-called LITER device is the subject of panels 19 – 24

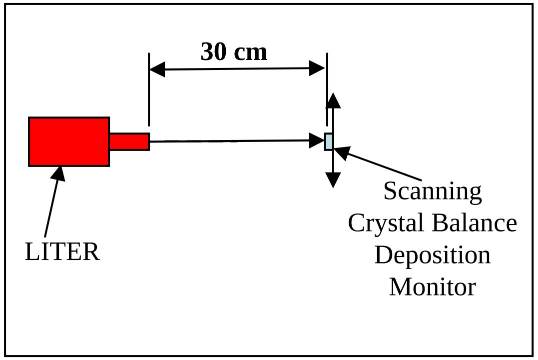
- **Panel 19 displays the new LITER mechanical and electrical designs**
- **Panels 20 summarizes the results of spatial measurements of LITER evaporation pattern.**
- **Panel 21 compares the measured evaporation rate against theory.**
- **Panel 22 displays the as-built and deployed NSTX evaporator.**
- **Panel 23 Summary and conclusions are presented.**

As-Built LITER Geometry on NSTX



Typical Gaussian Least-Fit to LITER Angular Distribution Measurements





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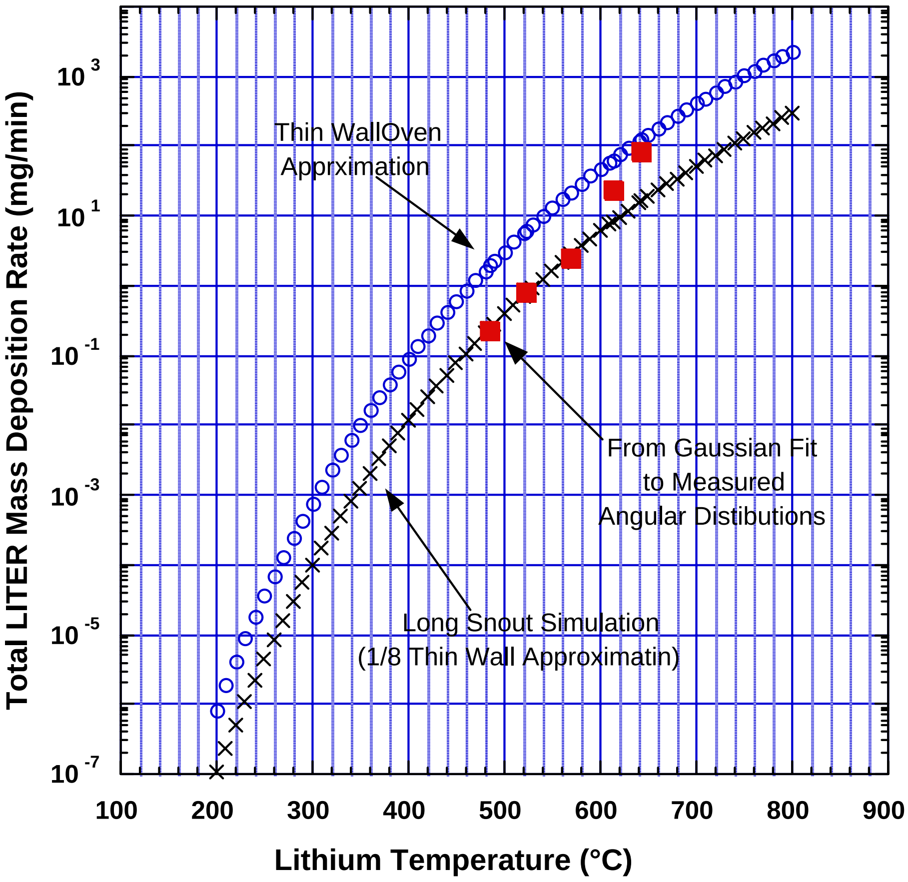
Comparison of Measured Total Mass Output with Thin Wall Approximation and Long Snout Simulation



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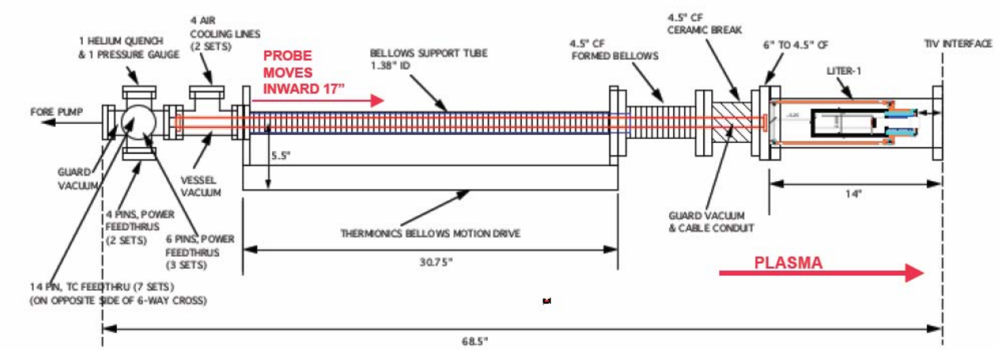
LITER Probe Installation on NSTX

Assembled View with Air-Cooled Guard Vacuum and He Quench



Summary and Conclusions

The development work on the Proto-LITER device demonstrated that:

- **The prototype reached useful levels of evaporation in either of two modes – the reservoir mode or the thermally-more-nimble snout mode.**
- **In the reservoir mode, from a starting temperature (~ 450 C) just below the lithium vapor point, the device could be brought to a high rate of deposition (~ 600 C) and cooled down (no evaporation) in about 15 minutes.**
- **In the snout mode, similar or even higher deposition rates were achieved and then shut off in ~ 1 minute. The collisionality of the Li vapor is important to this mode; hence the snout was run at ~ 800 C while the reservoir was kept at ~ 350 C.**
- **A reasonably good relative measurement of the remaining Li inventory could be made by observing the heat of fusion as the Li solidified during cool-down.**