
Update on IFE Target Fabrication

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Presented by Dan Goodin

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University of California, San Diego



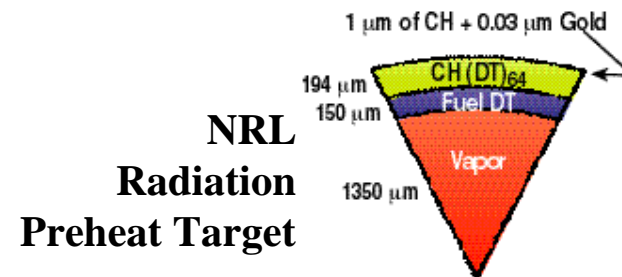
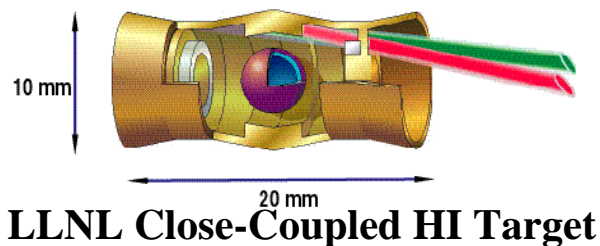
Topics to be discussed

1. Report on tritium inventory for the Target Fabrication Facility - meeting at LANL, 11/13/00.
2. Potential tritium inventory reduction methods.
3. Analysis of mass-production layering for HI targets.
4. Experimental evaluation of fluidized beds for high-volume target coatings

OTHER (NON-FABRICATION) UPDATES

5. Target thermal exposure experiment design
6. Results of target injection/tracking design review
7. Effect of chamber wall emissivity on target heating

We are addressing target fabrication for both direct and indirect drive targets:

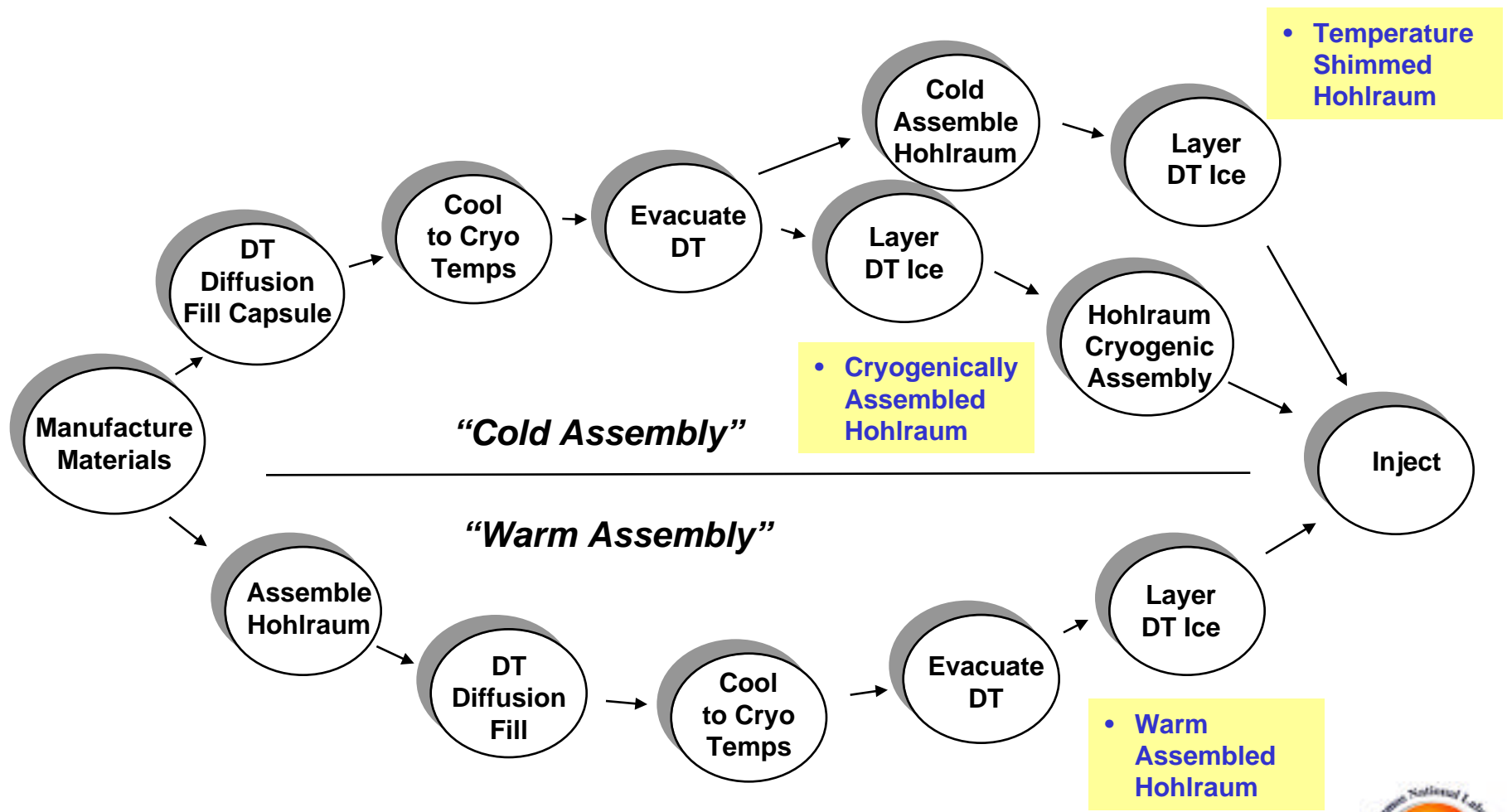


Target Fabrication Facility tritium inventory meeting

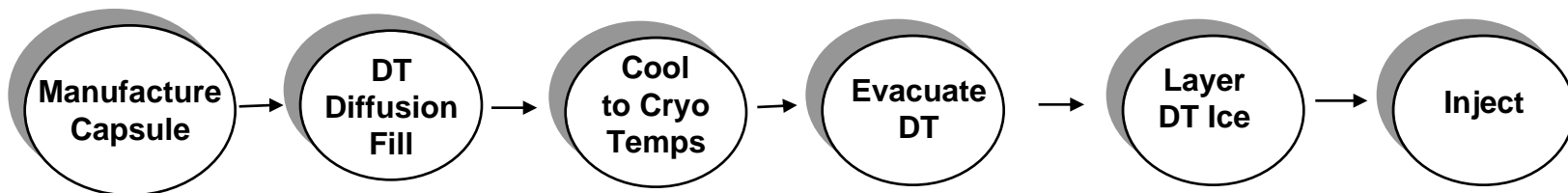
- **Workshop at Los Alamos attended by the following:**
 - LANL (Nobile, Gobby, Steckle, Schwendt)
 - GA (Goodin).
 - LLNL (Latkowski)
 - INEEL (Petti)
 - ANL (Sze)
- **Goal = discuss current status of work to evaluate required tritium inventories for different target designs and filling schemes**
- **Conclusions:**
 - Best to keep TFF inventory <250 g (releasable)
 - Need to keep TFF inventory less than ~1 kg
 - Continue to improve LANL tritium inventory model
- **Action items (in progress):**
 - Evaluate differences in target filling assumptions (buckle pressure, permeation coefficients, activation energies) between GA and LANL model (complete)
 - Evaluate isotopic exchange during filling process
 - Evaluate possibility of a LiDT target shell
 - Evaluate tritium inventory in stainless steel fill vessel



Three routes to fabrication and filling of the HIF IFE target are possible

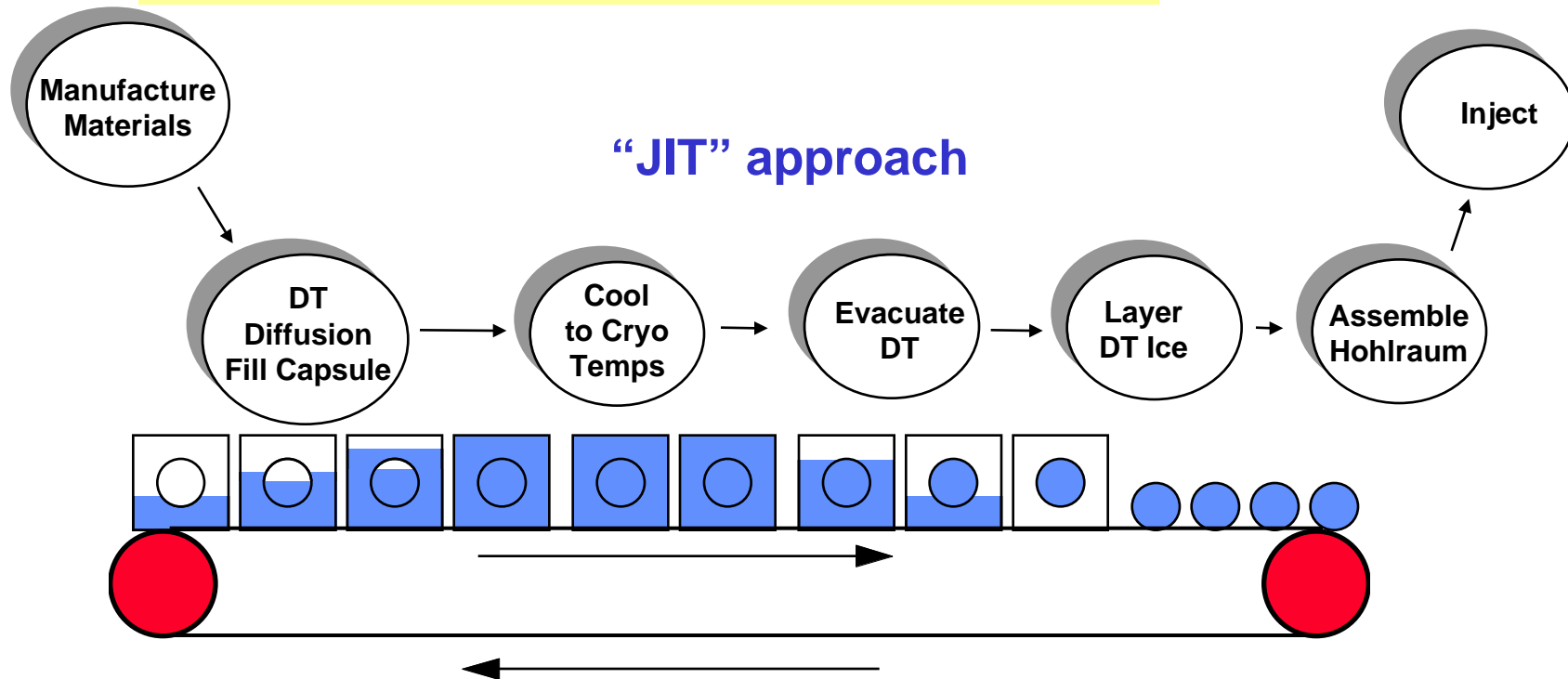


Fabrication and filling of the direct drive target is simpler



We are evaluating the minimum tritium inventory required for IFE plants

Cold Assembly (cryogenically assembled hohlraum)



Targets are processed at the rate necessary for injection
Benefit of model: eliminates engineering assumptions

DT Inventories have been evaluated for fill in hohlraum, fill before assembly, and direct drive

Theoretical minimum inventory (Actual inventories will be higher)

Buckle Pressure	HIF-III in hohlraum	HIF-III before assembly	Direct Drive
Fill Time	242 s	242 s	205 s
DT inventory with (Tritium) (1.1e15)	4 hours	4 hours	2 days
DT inventory with beta-layer (1.1e15)	58.4 kA (1.3e kA)	1.2 kA (0.3 kA)	8.8 kA (2.3 kA)
DT inventory with beta-layer + IR (1.1e15)	58.4 kA (1.3e kA)	1.0 kA (0.3e kA)	8.4 kA (2.0 kA)

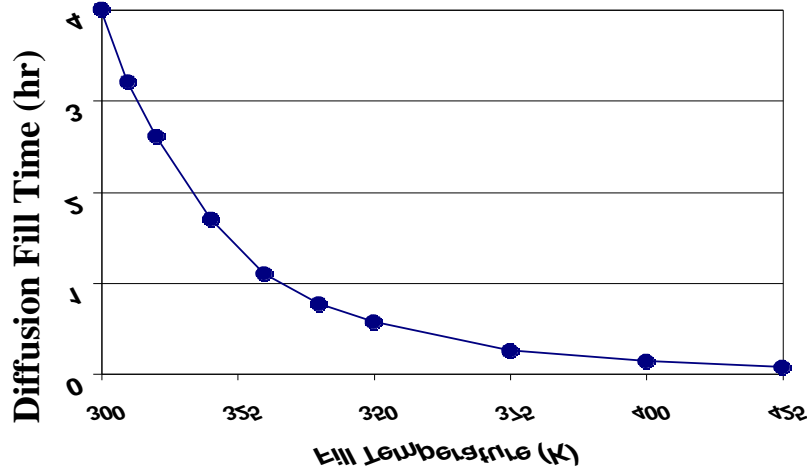
- Void fraction – 0.33
- Fill Temp – 25°C
- Cool time - 2 hr
- Evac time - 1 hr
- β layer time - 8 hr
- IR layer time - 2 hr
- Fill overpressures are 75% of buckle pressure

- The above analysis has been performed to evaluate “minimum” tritium inventory - this allows comparison of inventories for different IFE approaches without assuming any engineering approach.
- “Actual” tritium inventories based on real engineering scenarios will be evaluated in the future.

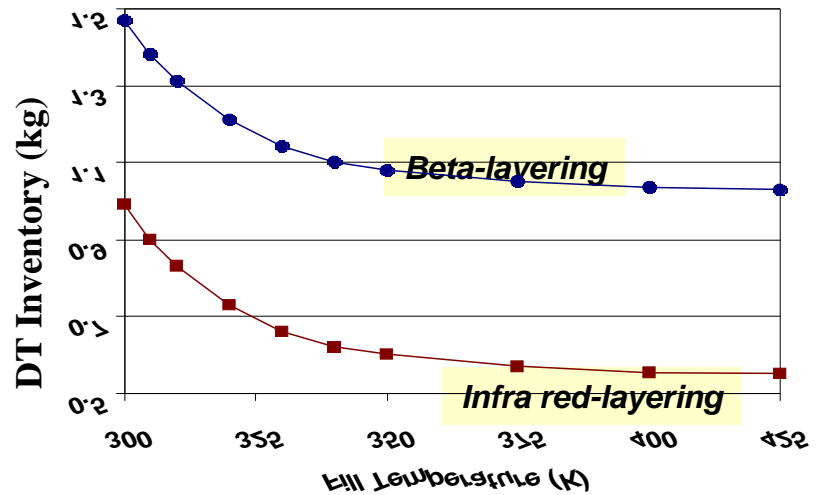
Increasing the capsule fill temperature decreases DT filling time and thus decreases the inventory

HIF Target (fill before assembly)

Higher temperatures decrease fill time



Shorter fill time decreases inventory



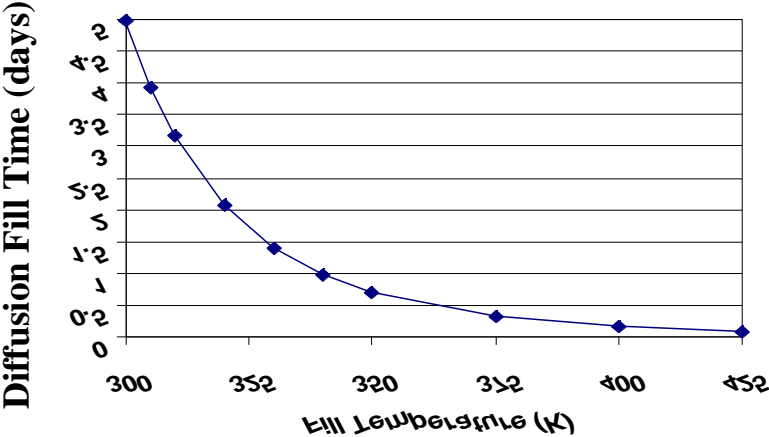
- Use of IR layering vs. beta-layering decreases tritium inventory
- Fill temperature is limited by melting temperature of GDP



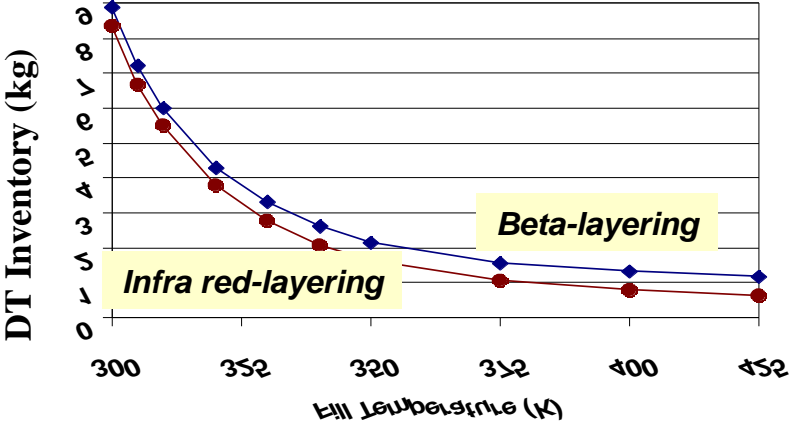
Increasing the capsule temperature during filling decreases the inventory for direct drive target

Direct Drive Target

Higher temperatures decrease fill time

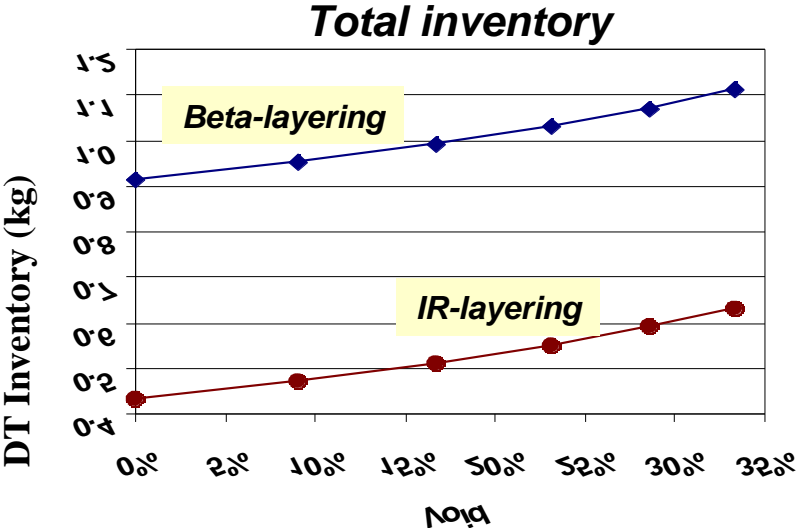
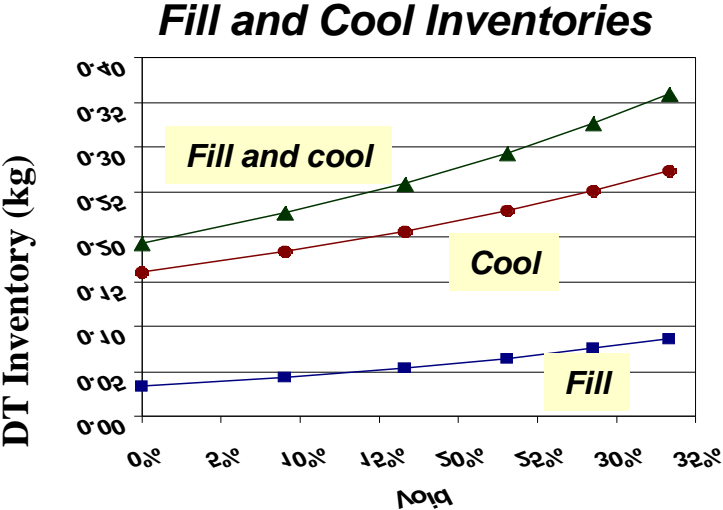


Shorter fill time decreases inventory

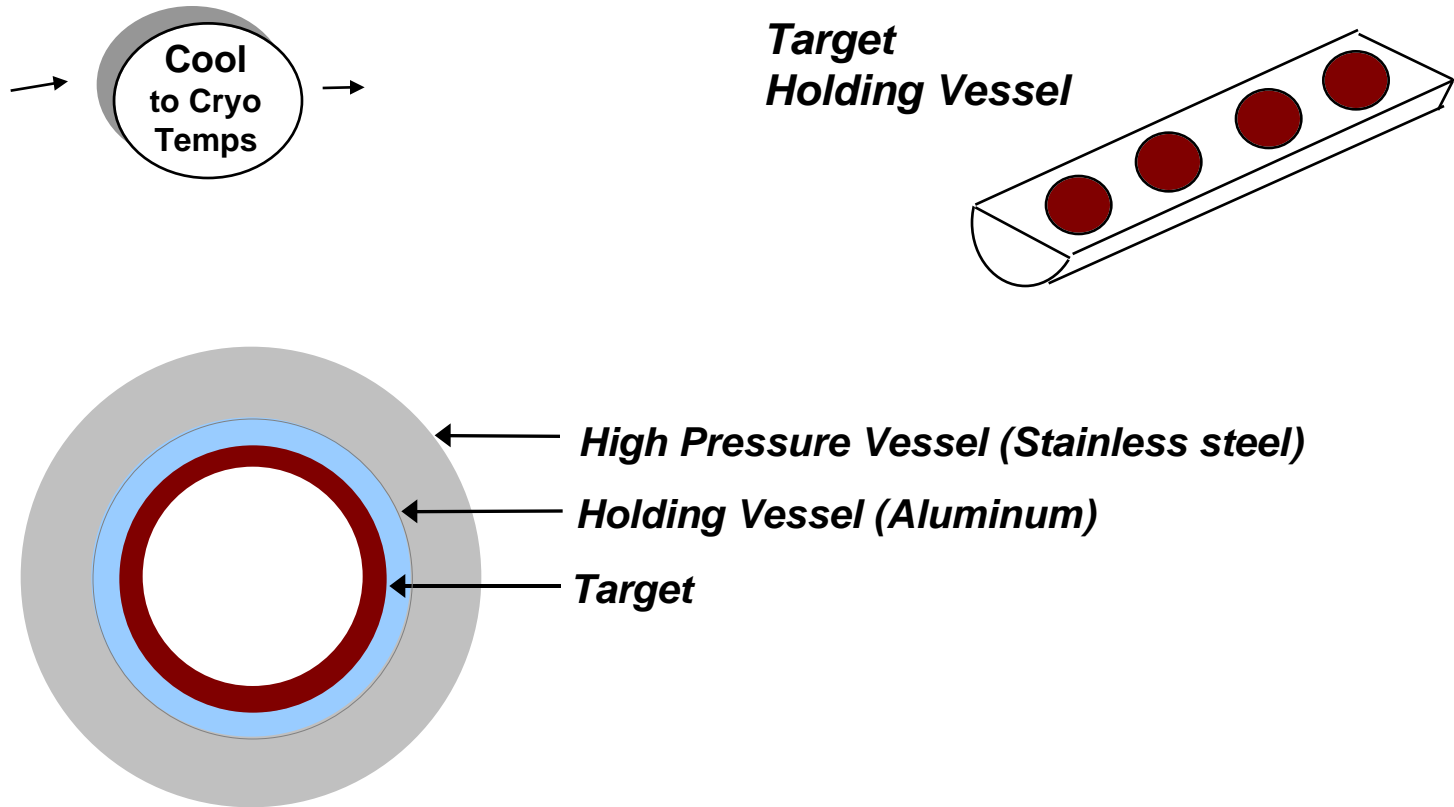


Decreasing the void volume in the fill system also decreases the inventory

DT Inventory vs. Void Fraction for Fill of an HIF Target
Fill Temperature – 340 K



The cooling time is a function of the material properties of the capsule, holding vessel, and high pressure cylinder



WORK IN PROGRESS

Calculations showed sensitivity of fill inventories to assumptions made and material properties

HIF TARGET, cold assembled, 300K

	BASE CASE	ALTERNATE CASE
Shell OD	0.530 cm	0.533 cm
Thickness	0.052 cm	0.055 cm
Elastic Modulus	3.5 GPa	1.6 GPa
Buckling pressure	242 atm	103 atm
Fill time	4 hours	11 hours
DT inventory (10% + 90% blowing) (Minimum inventory)	1.0 kg (0.6 kg)	1.3 kg (1.1 kg)

- Comparison of LANL and GA calculations revealed differences in material parameters
- Differences yield noticeably different results and demonstrate sensitivity of inventory to material properties and parameters

Methods are available to reduce IFE plant tritium inventories

- Reducing tritium inventories in HIF and Direct Drive Target Fabrication Facilities necessitates the following:
 - Diffusion fill of HIF capsules before assembly (cold assembly).
 - Diffusion fill at temperatures as high as feasible.
 - Minimize dead-space in fill system.
 - Minimize DT ice layering times through use of enhanced layering methods (IR layering)

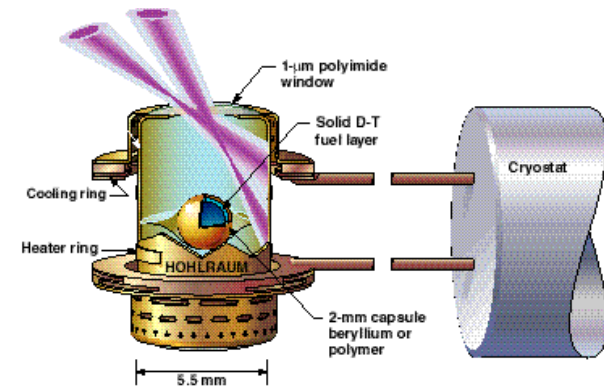
FUTURE WORK

- Model the cooling process
- Bring on-going experimental data into evaluations of buckle pressure and fill time calculations
- Continue to implement “real” engineering assumptions into models.

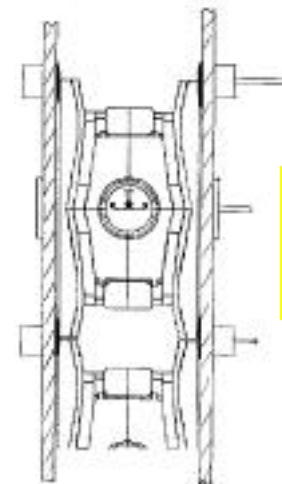


Analyses of mass-production layering for HI targets is beginning

- Proposed “temperature shimmed hohlraum” (TSH) layering method:
 - Primary layering method for NIF indirect drive
 - Critical feature = allows layering of fusion fuel after assembly of the hohlraum
 - This eliminates the need for “last second” assembly
 - Use of TSH in mass-production being evaluated under grant from OFES
- Mass-production requires reuse of expensive components:
 - Must provide required isothermal conditions at target capsule
 - Issue is precision of required temperature control
 - Evaluating staging of assembled hohlraums in vertical or horizontal tubes
 - Other options



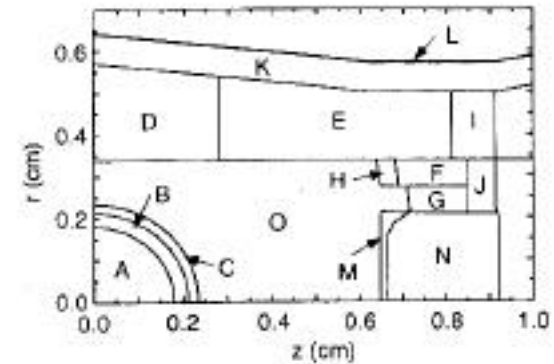
**TSH Configuration
For NIF**



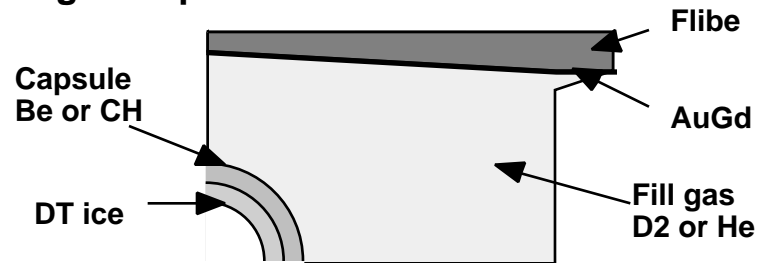
**Tube
Layering
For IFE**

Preliminary layering analyses show difficulty depends highly on capsule conductivity

- Requirements - DT ice temperature at a given radius must be uniform to $\sim 25\mu\text{K}$ to assure layer geometry (based on LLNL calculations for ICF)
- Question = what external temperature distribution is required to achieve this?
- Initial analyses assume fill gas in hohlraum
 - 35 mtorr of He
 - For a uniform hohlraum surface temperature:
Be capsule (high conductivity) DT $\Delta T = 3\mu\text{K}$
CH capsule (low conductivity) DT $\Delta T = 10\text{mK}$
 - Temperature shimming is required for CH



Section of HI Target



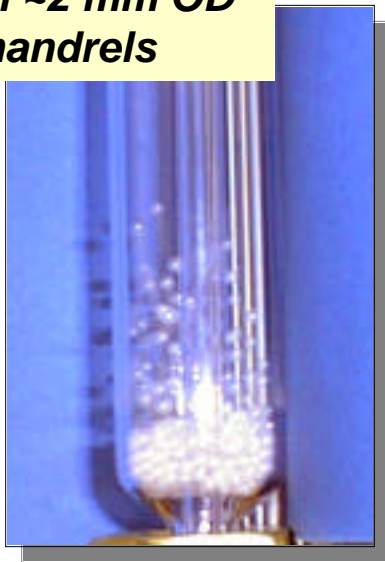
Simplified heat transfer model

- Work is just beginning
- Objective = conceptual design of a layering system for hohlraums

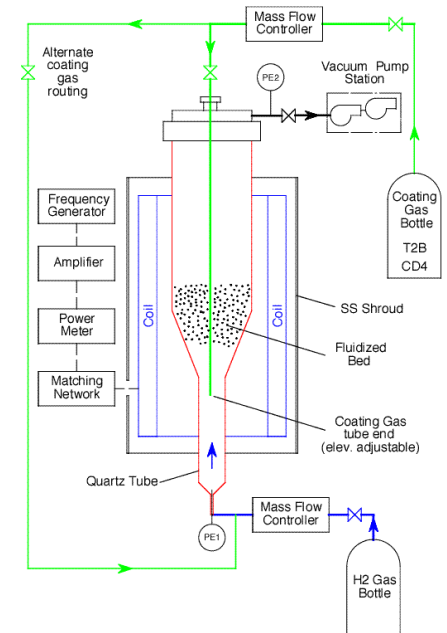
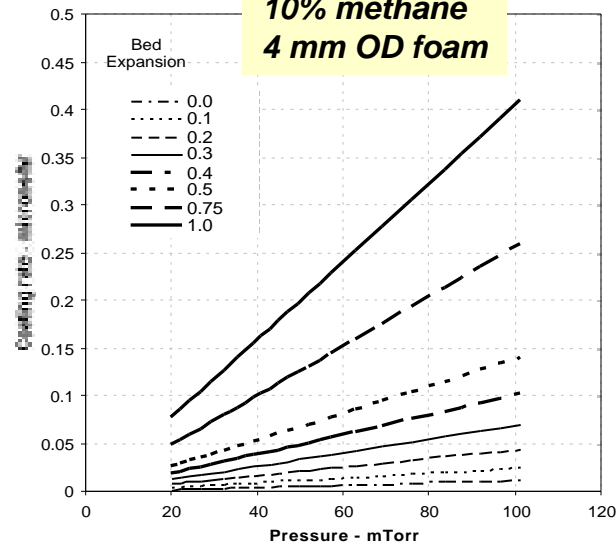
Experimental evaluation of fluidized beds for high-volume target coatings is beginning

- Goal is to extend fluidized bed technology to regime for IFE coatings
- Initial calculations of fluidization conditions & procurement of equipment were done under IR&D
- Now setting up experimental equipment for GDP coating
- Could also coat polyimide layers

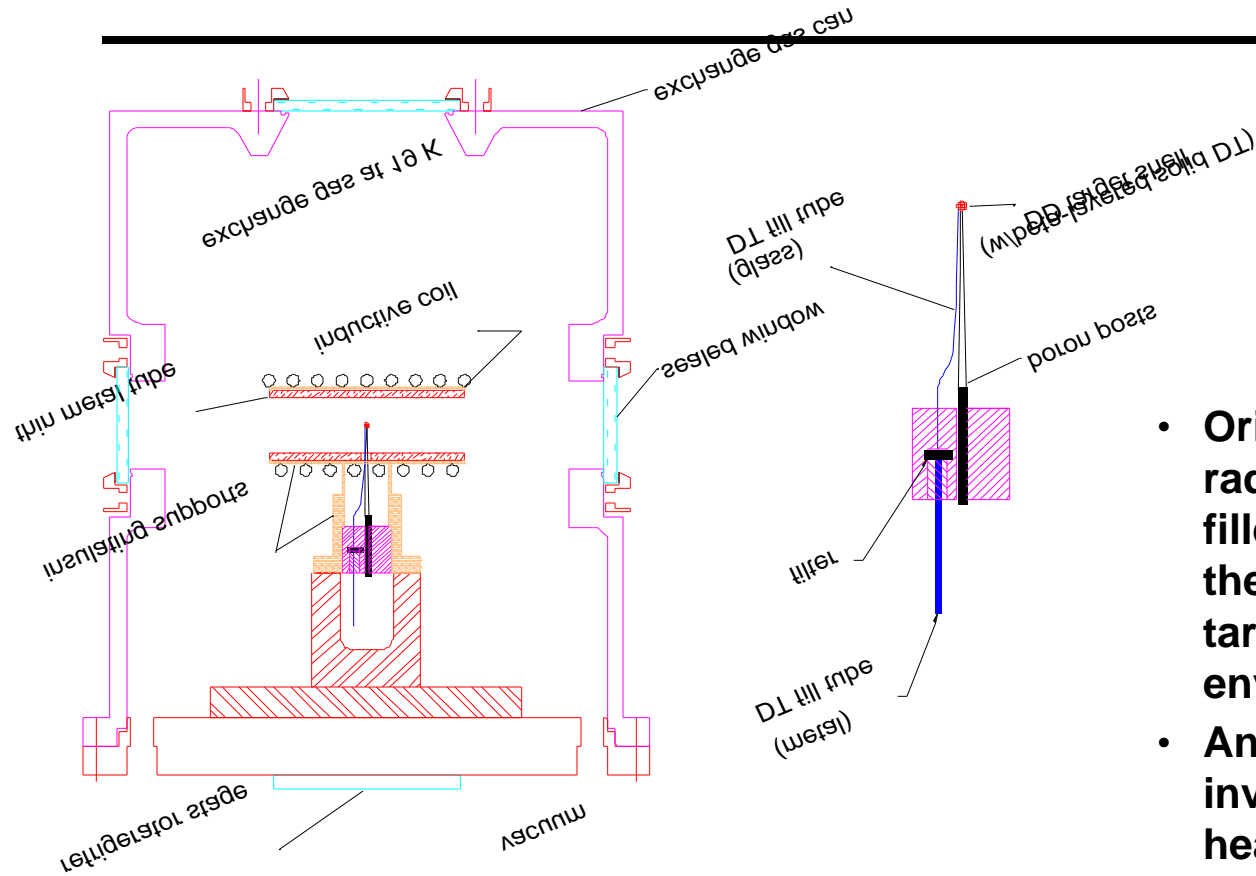
Bed with ~2 mm OD PAMS mandrels



90% hydrogen
10% methane
4 mm OD foam



An experiment is being designed at LANL to evaluate the effects of radiation heating of the target from the target chamber wall



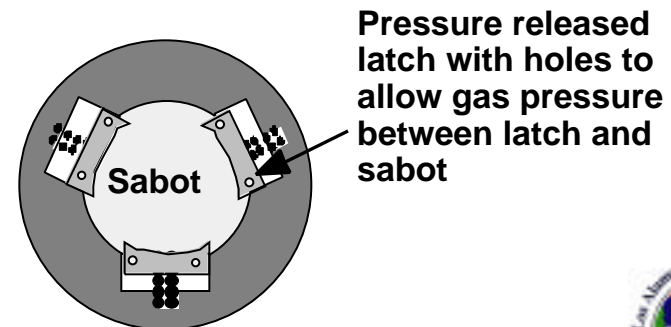
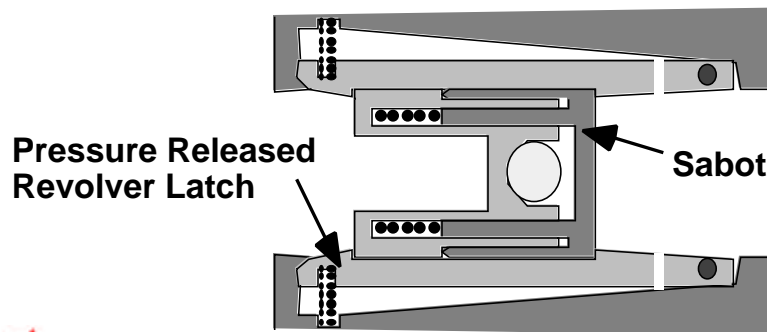
Radiative heating approach

- Original approach involved radiative heating of a DT filled target to understand the thermal response of the target to the chamber environment.
- An alternate approach that involves direct conduction heating of a DT ice layer in a cylindrical sample is being considered.
- Further work needed to evaluate optimum approach.

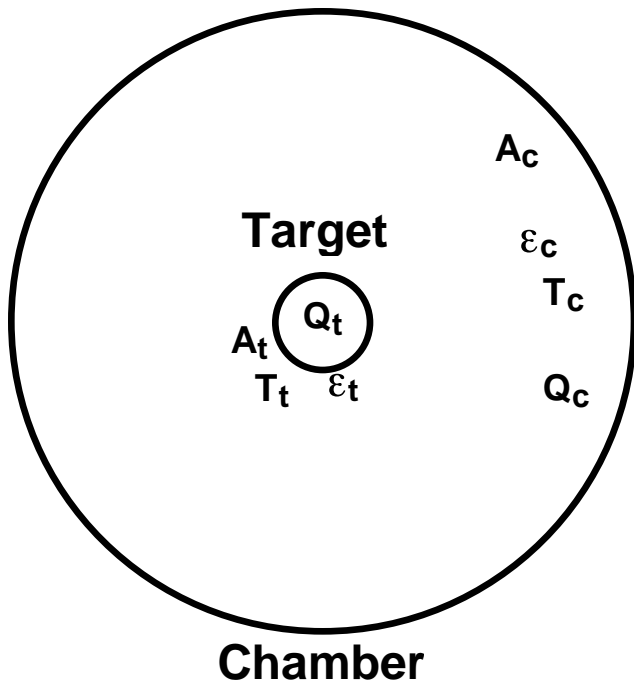
Conceptual design review for the target injection/tracking system was completed 9/00

- Five member independent review committee
- Expertise in mechanical design, instrumentation and control, physics/optics, and quality assurance
- Chairman's Report = Design is a reasonable approach, adequately developed, and no major issues not addressed by project personnel
- A number of detailed recommendations for evaluation or improvement were made that are being addressed in preliminary design

Example - a modified direct drive sabot latch design allows greater unlatching force



Target chamber emissivity does not affect target heating during injection in a Sombrero-like chamber



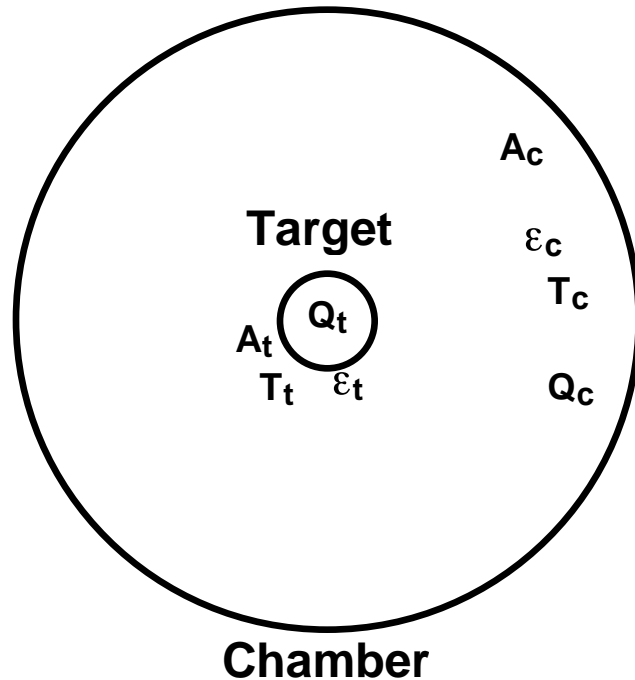
- Question regarding effect of chamber emissivity on calculated target heating during injection was raised at previous ARIES meeting
- Answer: Chamber emissivity does not affect target heating if the chamber wall reflections are diffuse (not specular)

$$Q_{tD} = \frac{A_t \sigma (T_c^4 - T_t^4)}{1/\epsilon_t + (A_t/A_c)[(1/\epsilon_c) - 1]} A_t \epsilon_t \sigma T_c^4$$

Diffuse chamber radiative heat flux

- We believe this equation gives the correct heat flux for a Sombrero-like chamber

Chamber emissivity could affect target heating in a liquid metal chamber



- A liquid metal or polished solid metal chamber could have predominantly specular reflections

$$Q_{tS} = \frac{A_t \sigma (T_c^4 - T_t^4)}{1/\epsilon_t + 1/\epsilon_c - 1} \quad \frac{A_t \sigma T_c^4}{1/\epsilon_t + 1/\epsilon_c - 1}$$

**Specular reflecting chamber radiative heat flux
(for a spherical target in the center of a spherical chamber)**

$$Q_{tS} \ll A_t \epsilon_t \sigma T_c^4 = Q_{tD} \text{ if } \epsilon_c \ll \epsilon_t \text{ and } \epsilon_c \ll 1$$

Less specularly reflected light per area reaches the target than reaches the chamber wall. Therefore, there is less energy absorbed than for diffuse reflections.

Reference: Robert Siegel and John Howell, Thermal Radiation Heat Transfer, Third Edition, Hemisphere Publishing Company, Washington (1992).

Summary and conclusions

- Progress is being made in demonstrating a credible pathway for mass-production of IFE targets
- Evaluations of Target Fabrication Facility tritium inventories are underway
 - Valuable exercise
 - Indicated where additional effort is needed:
 - Evaluation of cold assembly methods for hohlraums (ID)
 - Examine possibility of direct injection of liquid DT into shell (DD)
- Methods for mass-production of IFE targets are being studied both analytically and experimentally
 - Overall process flows
 - Layering in hohlraums (temperature shimmed hohlraum)
 - Fluidized beds for high-volume coating processes
 - Equipment is being designed to evaluate the effects of rapid heating during injection upon DT ice
- Design of target injection & tracking experimental equipment is proceeding
- Evaluations of target heating during injection are continuing