Lithium Hydride Issues

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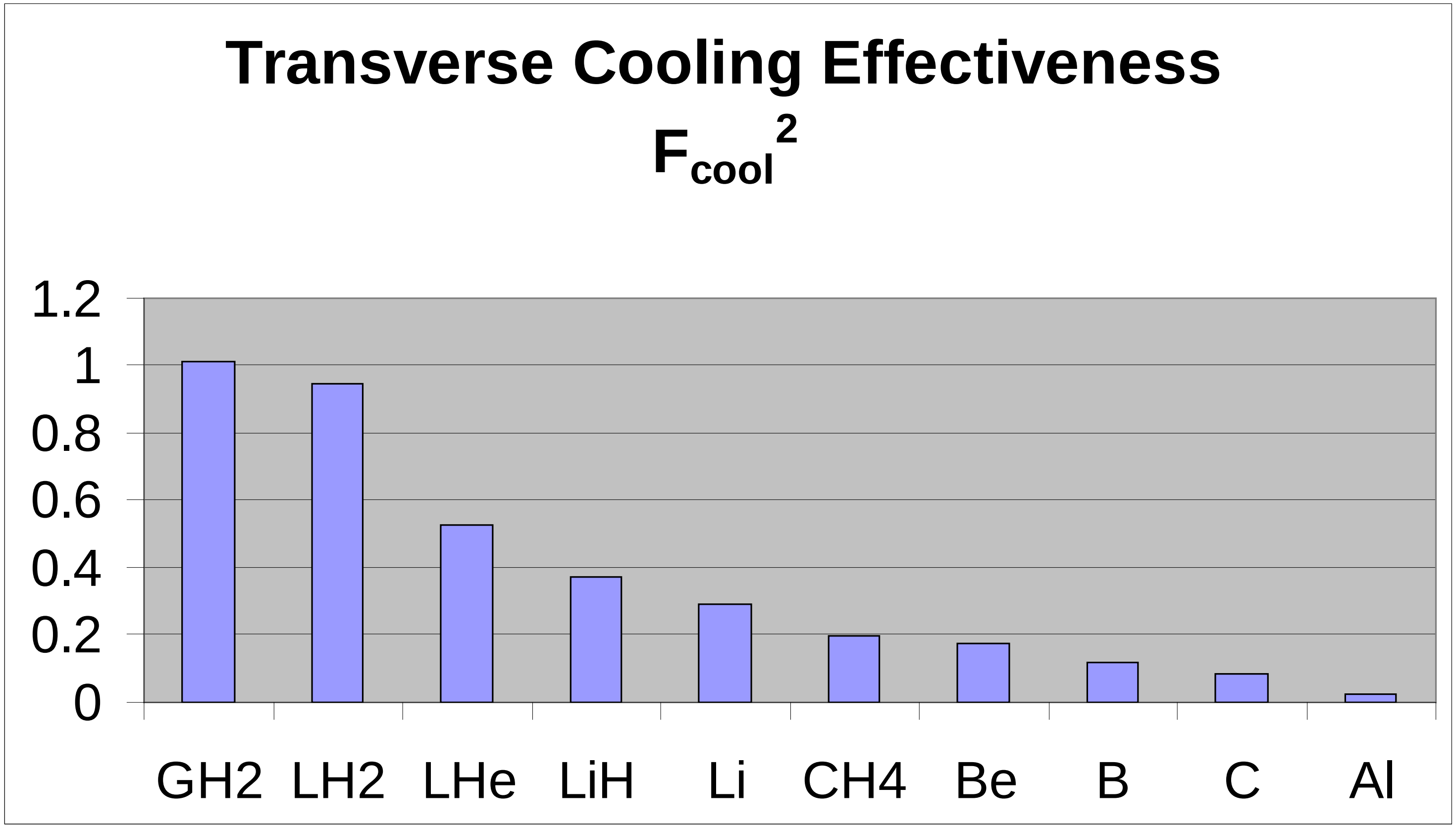
- Comparison of absorber materials
- LiH Safety Issues
- LiH Thermal Issues
- Fabrication and Ballpark Costs
- Possible Fabrication/Handling Scenario

Comparison of Absorber Materials



Definition of F_{cool}

F_{cool} is the fractional Energy-loss per radiation length.

The standard equation for Ionization cooling of transverse emittance:

$$\frac{d\varepsilon}{ds} = -\frac{1}{\beta^2}\left\langle\frac{dE}{ds}\right\rangle\frac{\varepsilon}{E} + \frac{1}{\beta^2}\;\frac{\beta_\perp (0.014)^2}{2E\;m L_R}$$

At equilibrium:

$$\varepsilon = \left[\frac{\beta_\perp (0.014)^2}{2E\;m}\right]\frac{E}{L_R\left\langle\frac{dE}{ds}\right\rangle} \equiv \left[\frac{\beta_\perp (0.014)^2}{2E\;m}\right]\frac{1}{F_{cool}}$$

F_{cool} characterizes the absorber material; the brackets characterize the lattice and kinematics. This ignores variations in $\beta_\perp$ over the varying thicknesses of the different absorber materials (which can be important, especially for LH2 windows). The 4-d transverse cooling effectiveness is the square of F_{cool}.

LiH Safety Issues

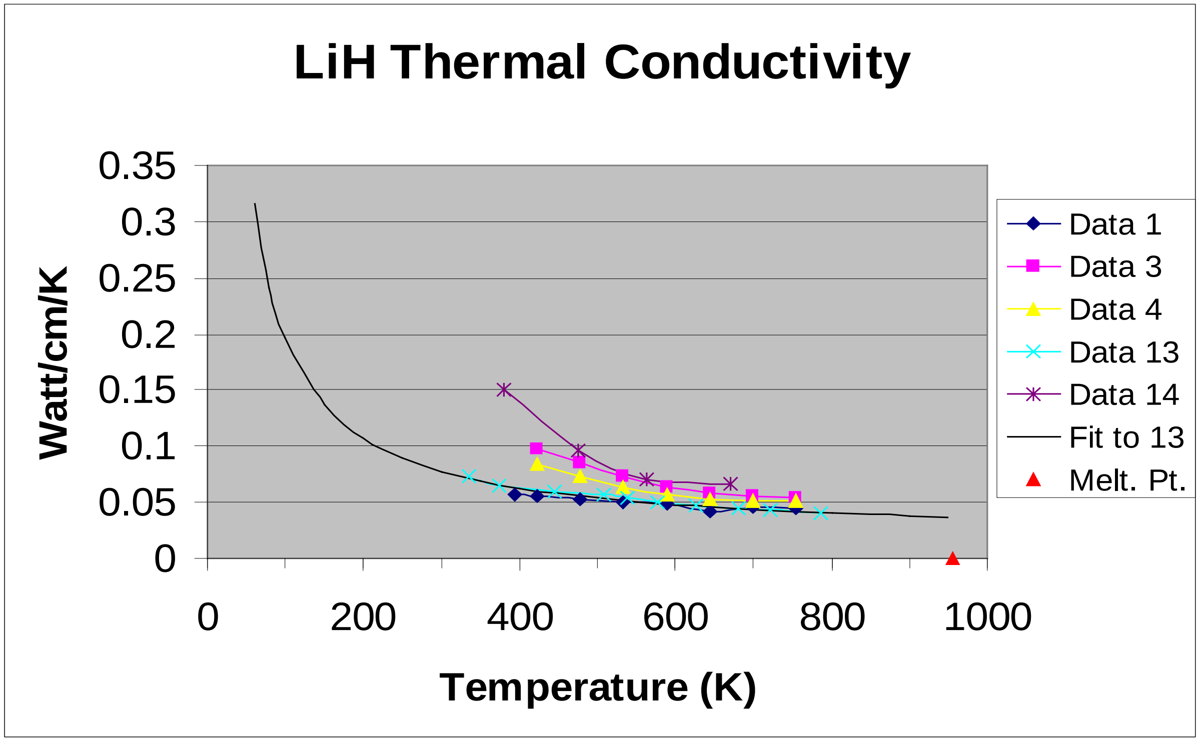
- LiH is a hazardous material; the safety issues are very different from those of liquid Hydrogen, but roughly comparable in difficulty.
- LiH reacts violently with water, so water cooling must be carefully designed and implemented (it's not certain it can be done safely). Halon fire suppression is probably required.
- Handling of prefabricated LiH is not terribly hazardous (gloves and dust masks); fabrication itself (casting) is best left to experts.
- Bare LiH can be pumped down to vacuum; it is best to re-pressurize with dry Nitrogen, but room air is OK.
- LiH cannot be in direct contact with aluminum (Al migrates).

LiH Thermal Issues

- Water cooling must be carefully designed and implemented, and may not be possible safely.
- LN_2 cooling seems a better choice than water (much higher thermal conductivity, lack of safety concerns), and may be desirable for reducing RF power I^2R dissipation, also.
- LiH is a pretty good conductor of heat – if good thermal conductivity to the mounting flange can be achieved, then edge cooling may be good enough for a linear channel, but not for a cooling ring (see below). But how do we achieve this (remember their thermal expansion rates are significantly different)?
- For optimistic intensities there will be large temperature gradients – will thermally-induced stresses be a problem?
- Radiation cooling is tiny compared to conduction.
- But LiH thermal properties are not very well known....

Thermal Properties of LiH

- From 293 K to 80 K, LiH contracts about 20% more than Al.
- LiH melts at 956 K.
- LiH thermal conductivity is not well known (varies with preparation?):



LiH Absorber Properties in a Cooling Channel

- Values are for a 5 cm thick 30 cm diameter LiH absorber (7.5 MeV loss) with edge at 80 K.
- Thermal conductivity assumed constant, estimated from above fit, for temperature ~20% below peak.
- Heating power and temperature rise both scale with intensity and with turns around a cooling ring.
- Half-aperture wedge absorbers will have significantly less heating power and lower peak temperatures (depends on details).

Beam mu/sec	**Ring Turns**	**Beam Sigma**		**Heating Power**	**Peak Temp.**
4×10^{14}	1	5 cm		482 W	145 K
4×10^{14}	1	2 cm		482 W	530 K
4×10^{14}	1	1 cm		482 W	**Melts**
4×10^{14}	10	5 cm => 3 cm		4.8 kW	**Melts**

LiH Fabrication and Ballpark Costs

- LiH is readily available, <$0.36/gm (often depleted of ^{6}Li).
- Several companies could fabricate absorbers.
- Fabrication requires a dry room (<2% rel. humid.) with steel walls and floors, proper safety clothing, etc.
- Absorbers would be cast (melts at 683º C).
- While costs cannot be accurately estimated without a realistic design, it will most likely be less than ~$10,000 for a set of 2 or 3 (not including stainless steel mounting collars).

Possible Fabrication/Handling Scenario

- We machine stainless steel mounting flanges and safety covers, and ship them to the LiH supplier; safety covers will also provide support during shipping and handling.
- The supplier casts the LiH to fit, installs it in the flanges, attaches the covers in the dry room, and ships to FNAL.
- Except for acceptance inspection (in a fume hood), the covers are left in place until mounted into the beamline.
- The last task before sealing the vacuum pipe is to remove the covers; the beamline is then pumped down as usual.
- When the beamline needs to be opened for maintenance, it is pressurized with dry N_2; after opening, the first task is to reattach the covers.
- In an emergency or accident, using room air to pressurize is OK (at worst the surface of the LiH will oxidize a bit).

Possible Fabrication/Handling Scenario

- Lots of those steps still need to be investigated:
  - How do we achieve good thermal contact between LiH and flange?
  - Will shipping fracture or crumble the LiH?
  - Use of a fume hood for acceptance inspection – is one available? Can it be flooded with dry N_2?
  - Even with covers in place should it be stored in a special dry room?
  - Can the beamline even be designed so the covers can be removed last?
  - How do we repressurize the beamline with dry N_2?
  - How much room moisture will get to the LiH before the covers are re-attached? – clearly this depends upon how much work is involved to get to the LiH to attach them.
  - How do we ensure the fire department never uses water near LiH? I assume Halon fire suppression systems will be used....
  - Surface oxidation from air moisture is almost inevitable; how will it affect the cooling performance?
- All of this needs to be reviewed and approved.