Brute Force with Gentle Touch: Vibration Isolation Techniques used to Increase HD Target Polarization

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Outline

- The HD target and the brute force polarization technique
- Heat load minimization through vibration isolation
- Did the techniques employed work?

LEGS Target Team

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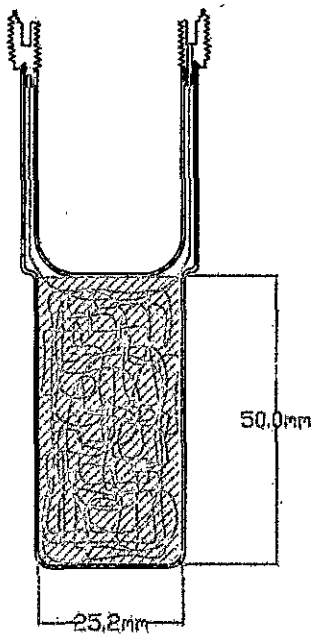
LEGS Polarized HD Target (SPHICE)

Polarized by conventional Brute Force and/or RF Forbidden Passage

- **Simple:**
  HD (Hydrogen deuteride)
  $H(p_{free}) + D(p_{bound} + n_{bound})$

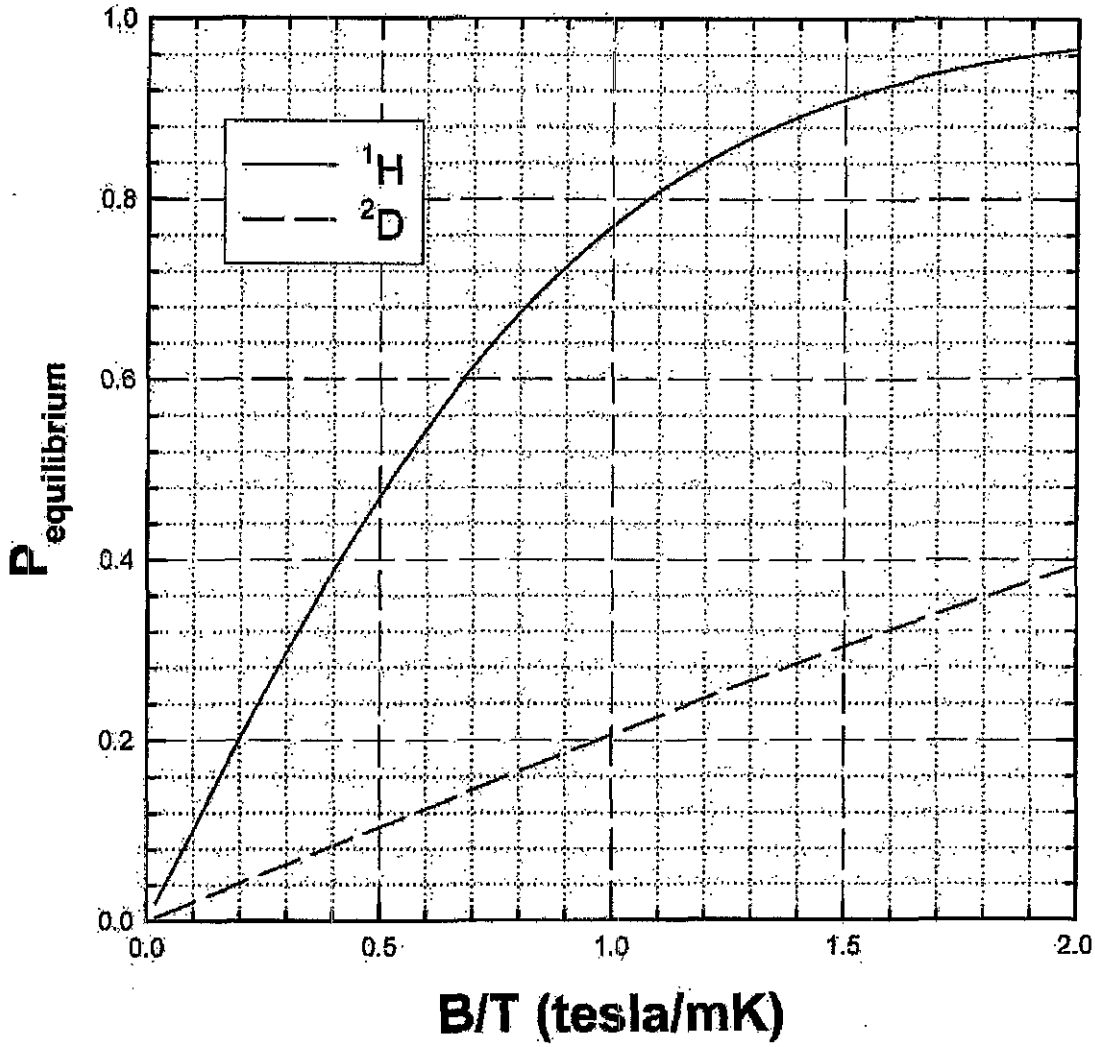


- **Low Background:**
  Contains HD + 20% Al wires + Kel-F end caps.

  Background can be easily subtracted by empty target cell measurement.

- **Portable via Frozen Spin:**
  Frozen spin switch allows for later use in lower B and higher T conditions.

Thermal Equilibrium Polarization for H and D



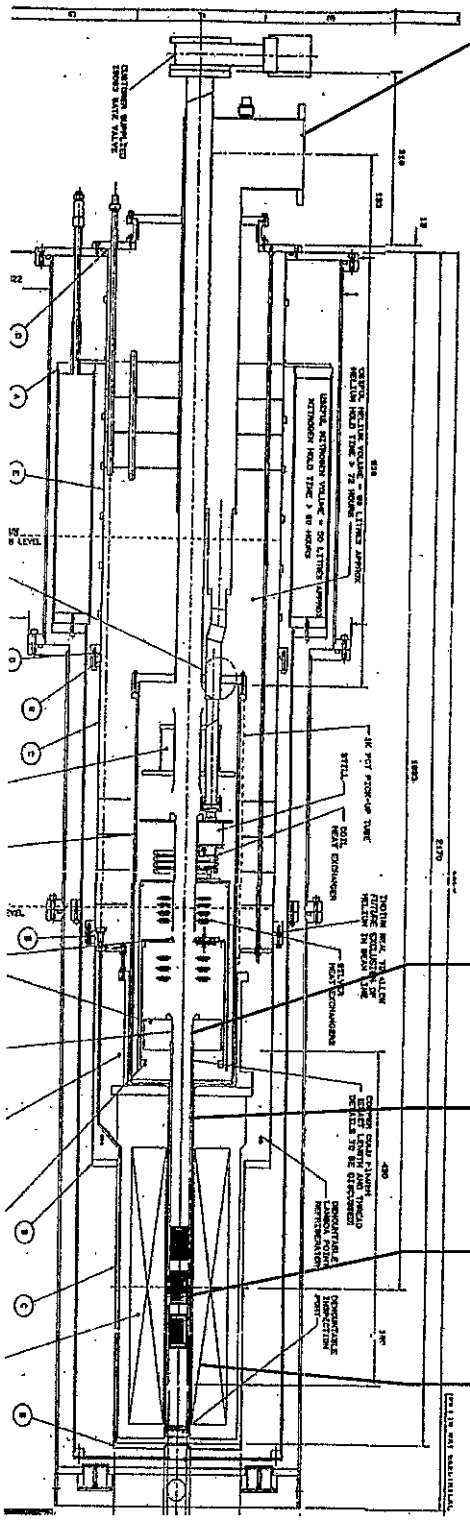
Brillouin function:

$$P_{TE}(x,I) = \frac{2I+1}{2I} cth\left(\frac{2I+1}{2I}x\right) - \frac{1}{2I} cth\left(\frac{x}{2I}\right)$$

$$x \equiv \frac{\mu B}{k_B T}$$

I=1/2 for H and 1 for D

The LEGS Dilution Refrigerator



Pumping Line

Base Temperature:

8.4mK

Magnetic Field:

15T@4.2K

17T@2.2K

Mixing Chamber

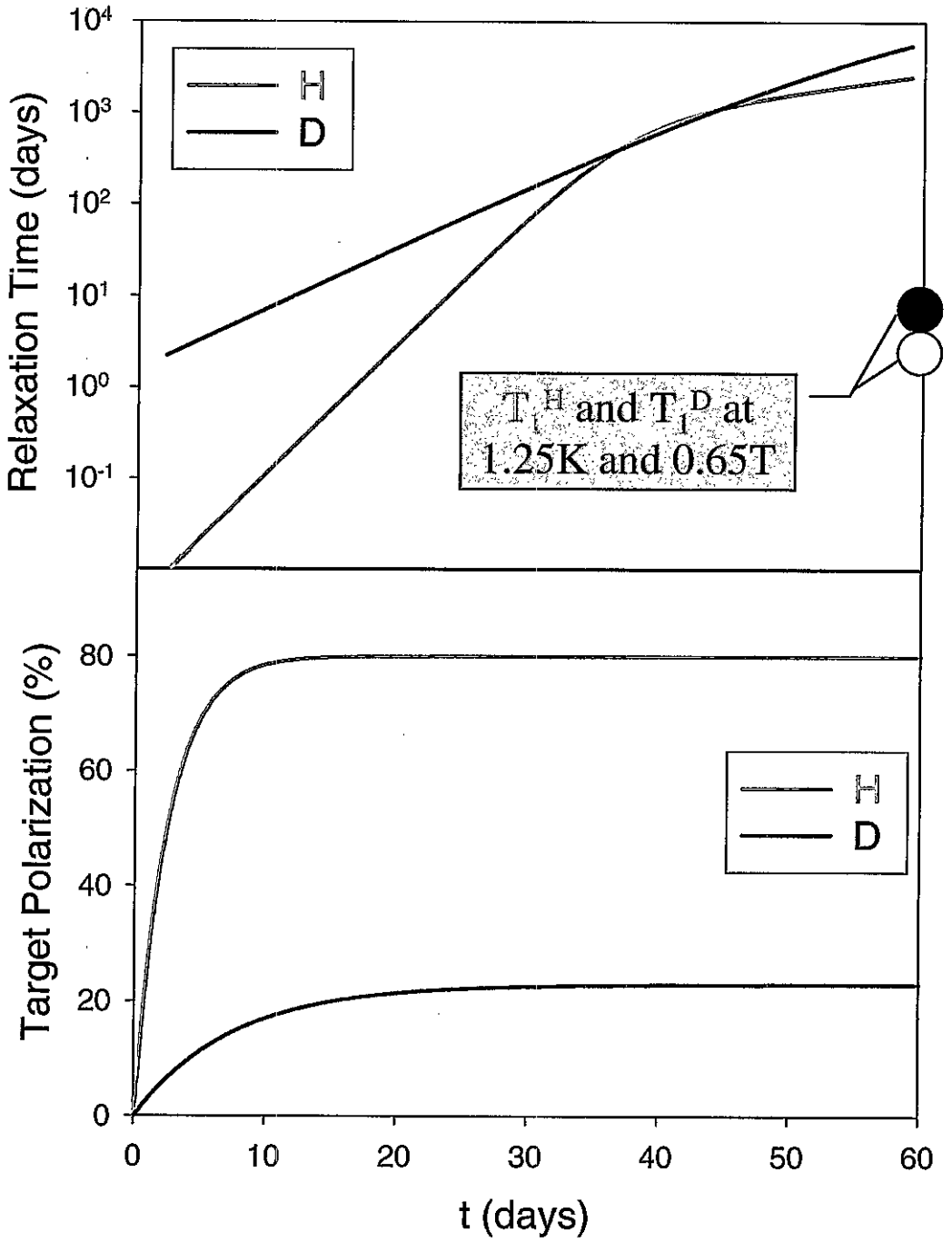
Cold-Finger

HD Targets

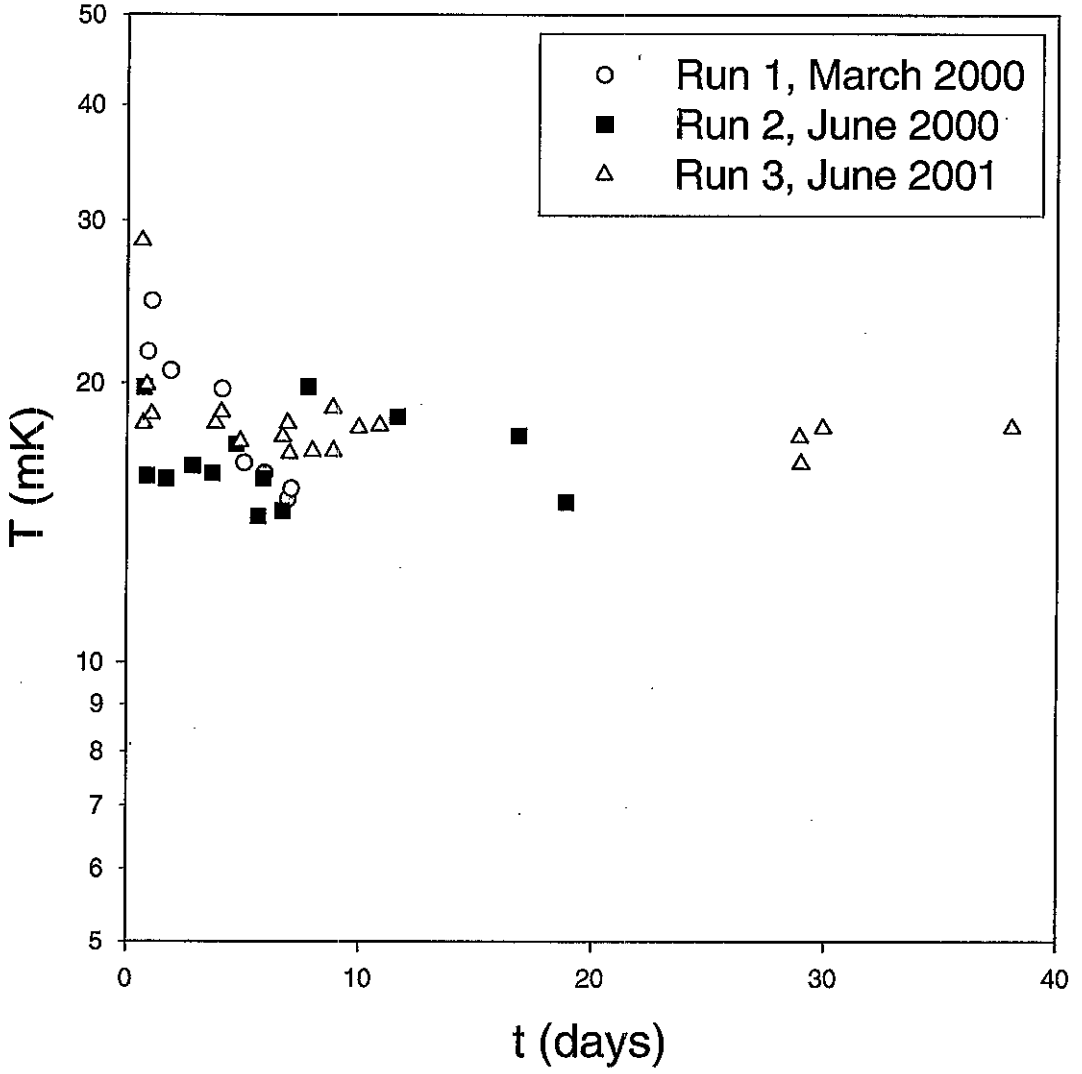
15/17T Magnet

Typical Target Condition

polarized at 15T and 12mK

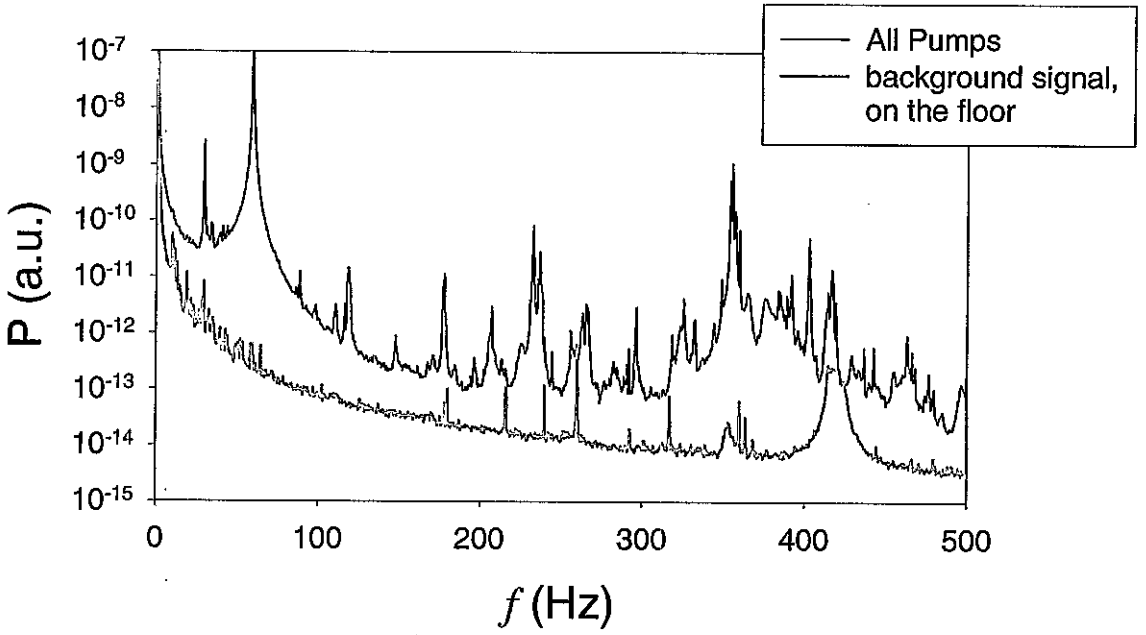


Cold-Finger Temperature without Vibration Isolator

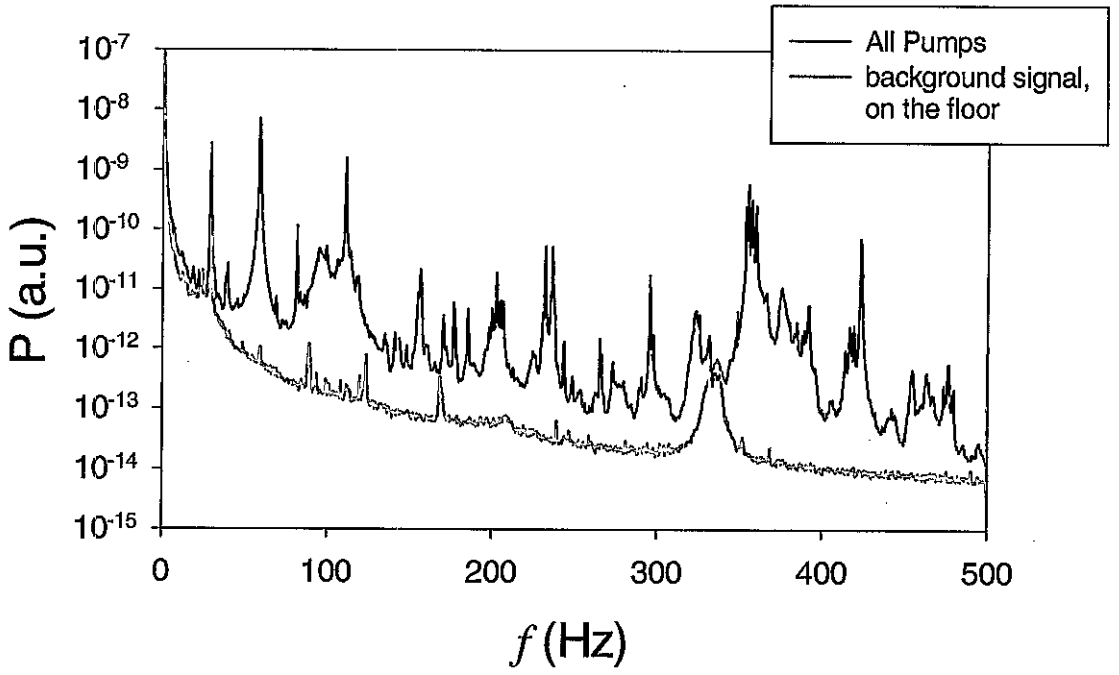


Pump Line Vibration

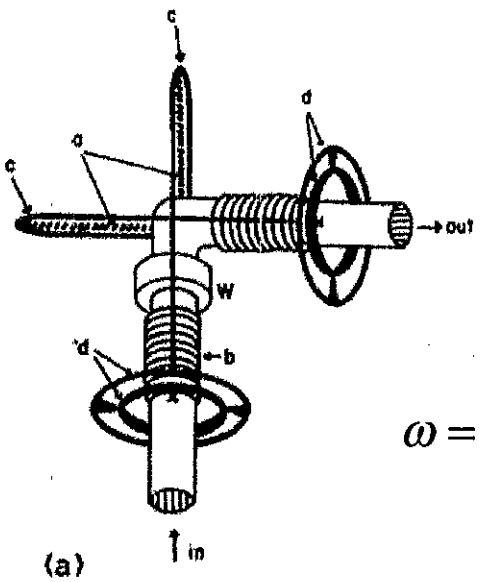
Vibration Heat Input Rate, Longitudinal



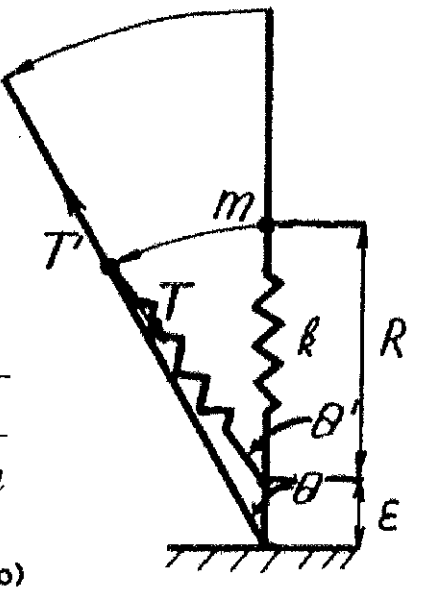
Vibration Heat Input Rate, Transverse



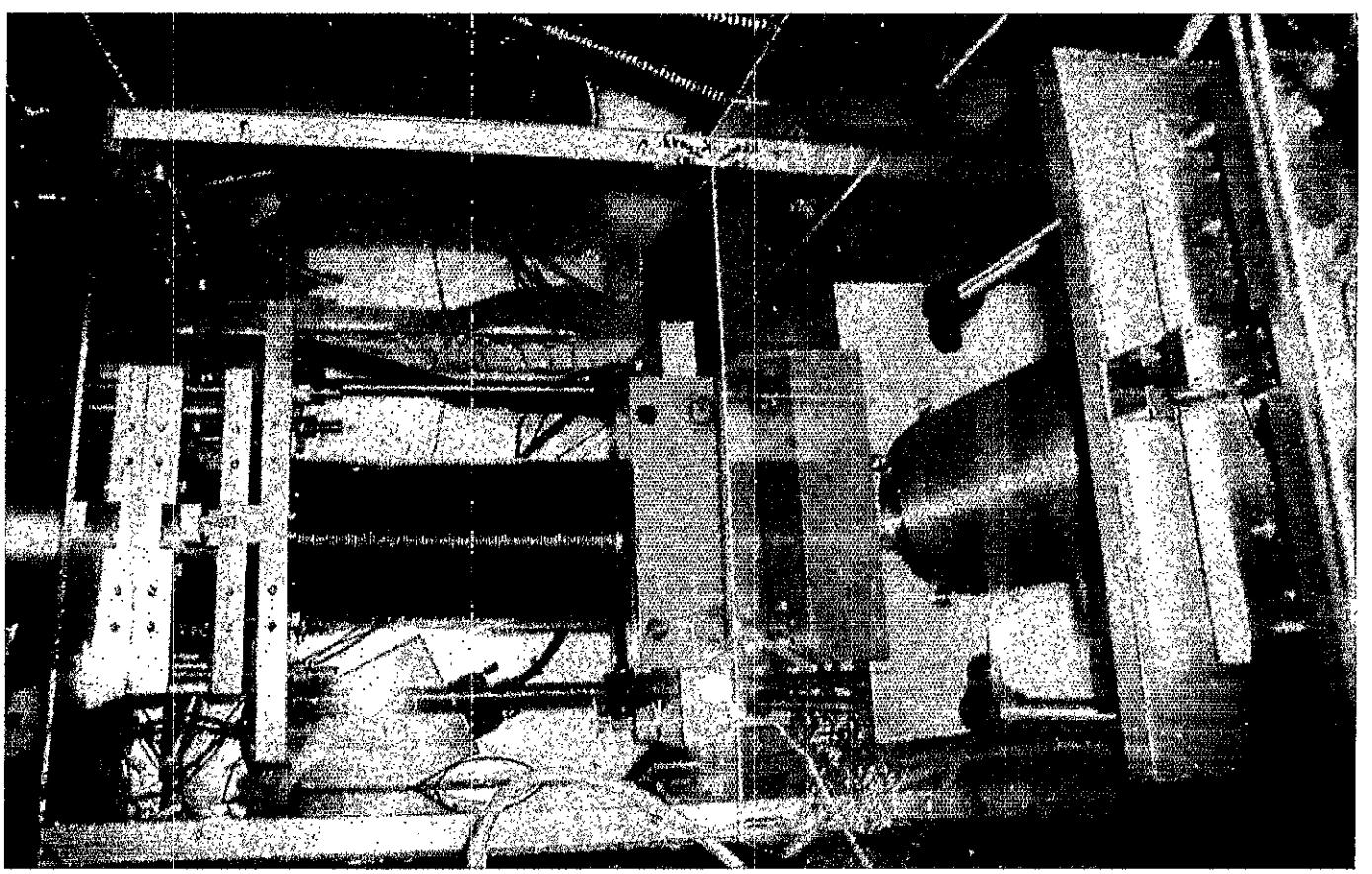
Pump Line Vibration Isolator



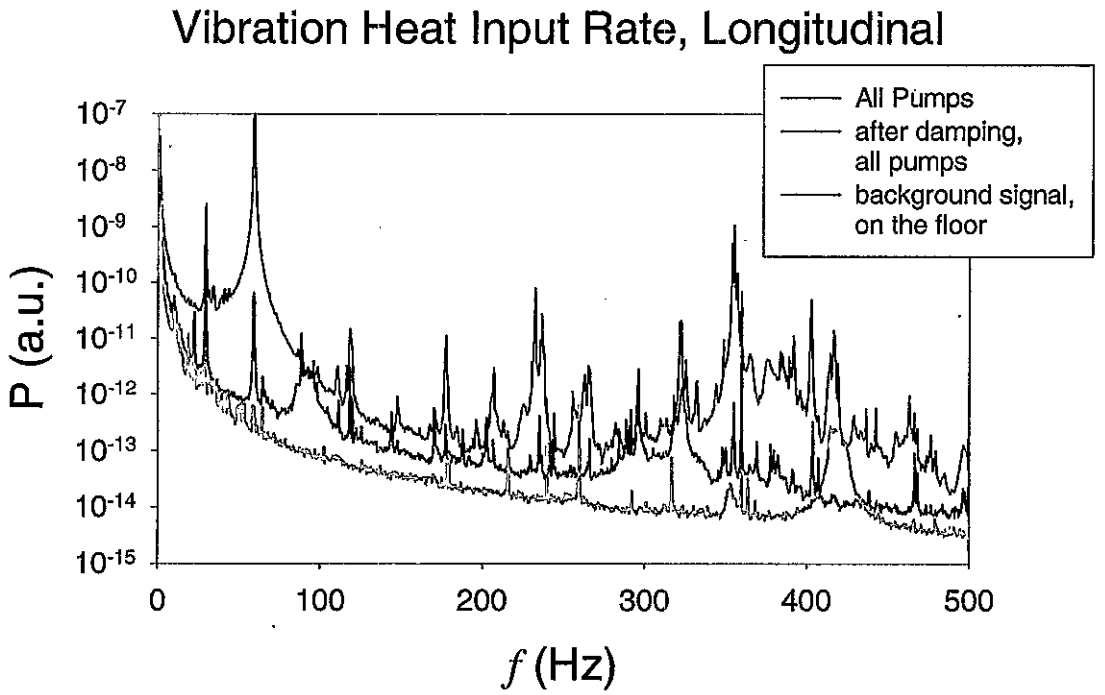
$$\omega = \sqrt{\frac{\varepsilon T}{4R^2 m}}$$

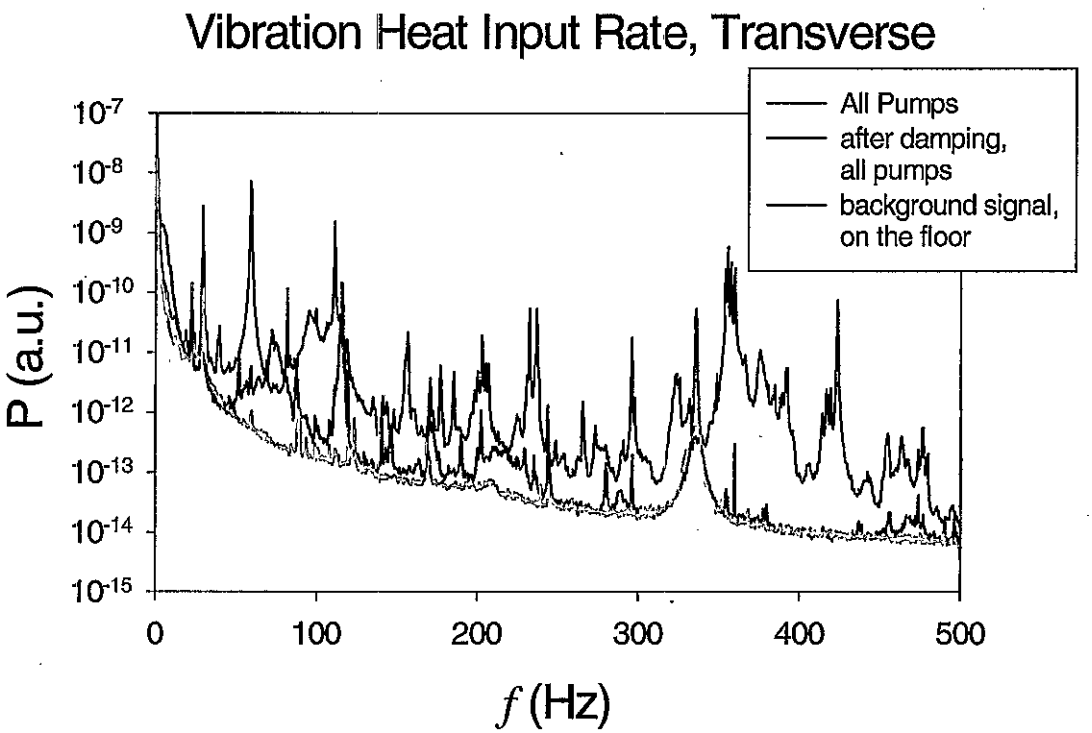


Kirk and Twerdochlib, Rev. Sci. Instrum., 49(6), Jun. 1978

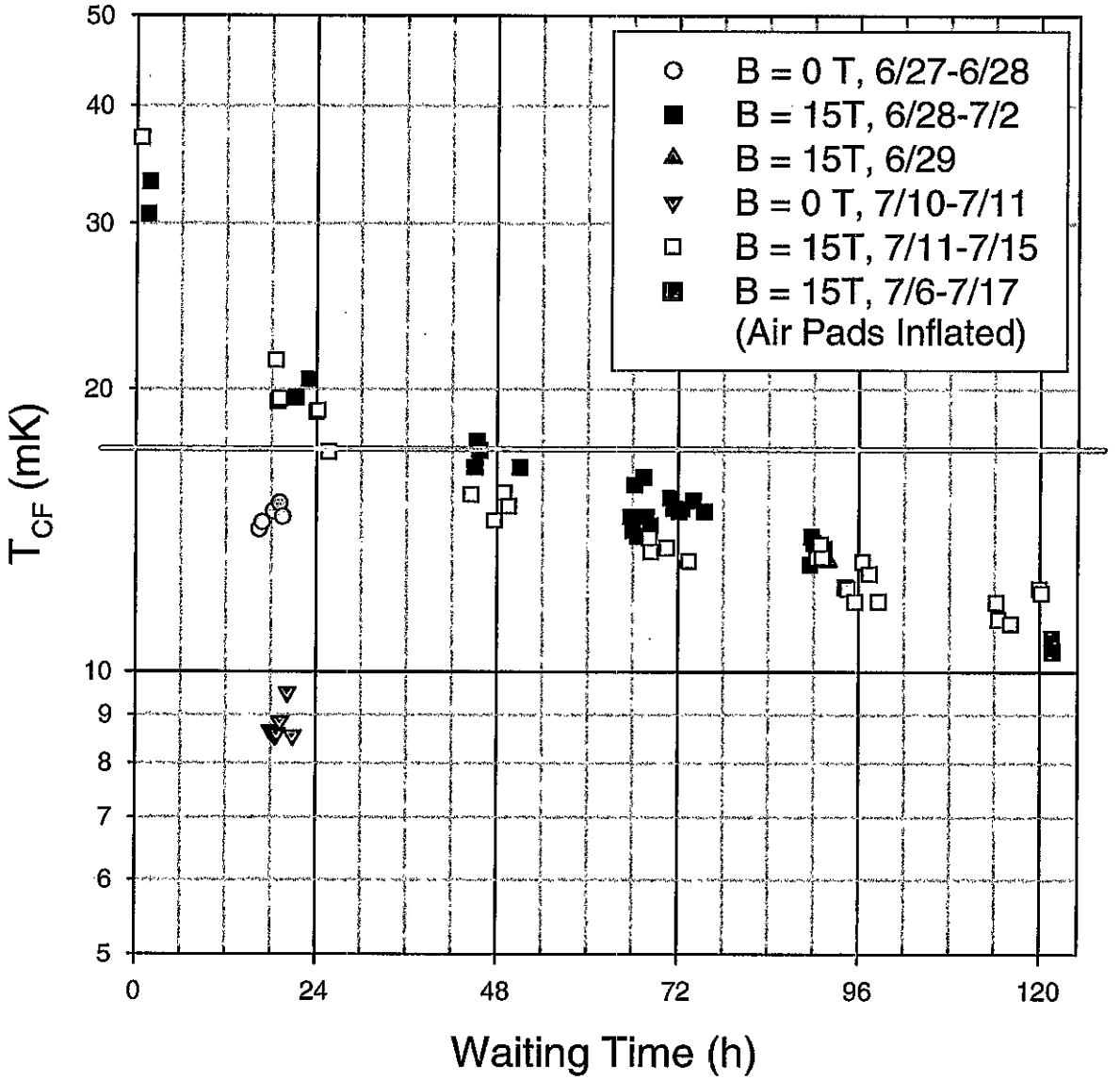


Results of Vibration Isolation

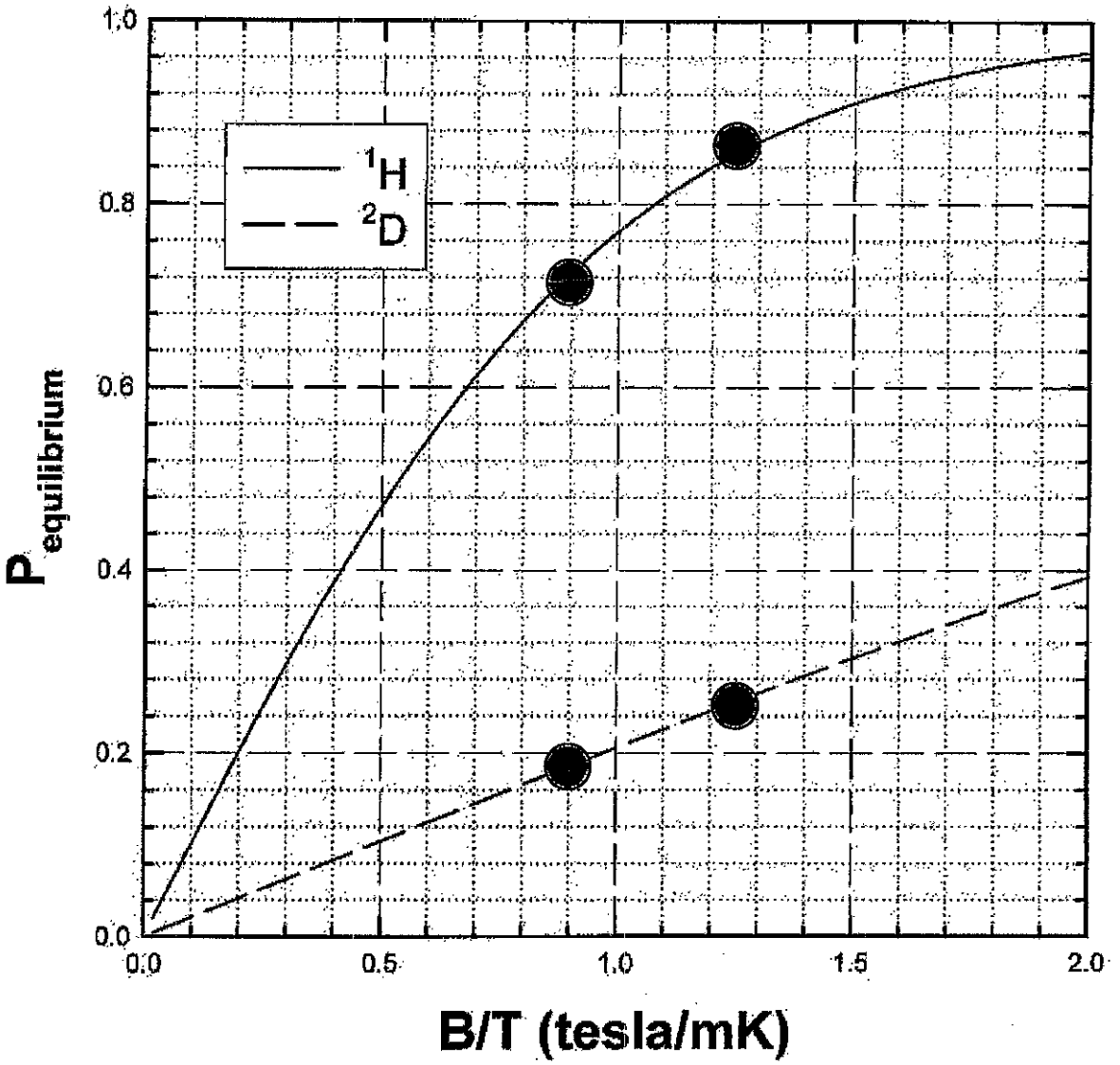




Cold-Finger Temperature after Utilizing Vibration Isolator



Polarization Projection for H and D



- *Old condition: B/T=15T/17mK=0.88*
- *New condition B/T=15T/12mK=1.25*

Summary

- Eddy current heating produced an undesirable temperature increase in the LEGS DF

- Vibration isolation techniques were employed to greatly reduce this heat load

- A substantial increase in HD target polarization will result from this implementation