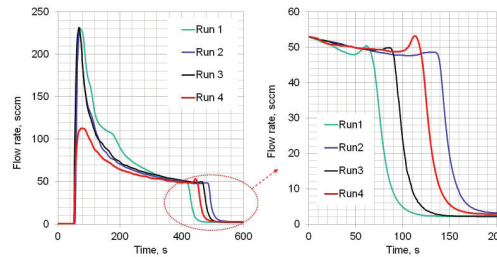# WARM-UP CALORIMETRY OF DEWAR-DETECTOR ASSEMBLIES
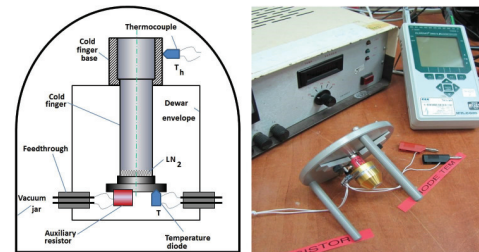
A VEPRIK, B SHLOMOVICH, A. TUITTO

SCD AND IMOD
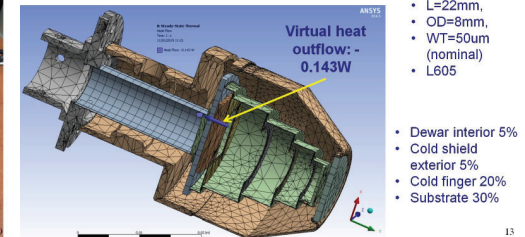

LN2 BOIL-OFF CALORIMETRY: PRACTICE AND LIMITATIONS

TYPICAL INCONSISTENCIES IN FLOW RATE MEASUREMENTS

EXPERIMENTATION SETUP

FE MODELING @150K

- L=22mm,
- OD=8mm,
- WT=50um (nominal)
- L605

Virtual heat outflow: - 0.143W

- Dewar interior 5%
- Cold shield exterior 5%
- Cold finger 20%
- Substrate 30%

DEWAR DETECTOR ASSEMBLY
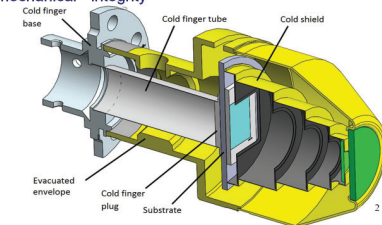
Elevated self heat load - loss of vacuum
- natural outgassing
- release of trapped contaminants
- insufficient mechanical integrity

LN2 BOIL-OFF CALORIMETRY:
- limited accuracy and repeatability, especially for short cold fingers
- not suitable for other than 77K applications
- heat load @ 77K can not be recalculated to another temperature

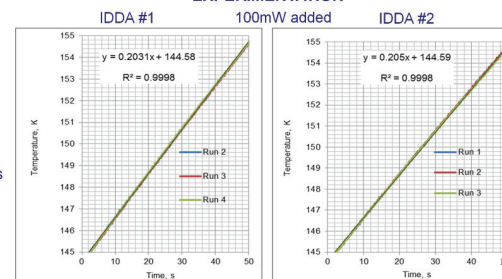## BOIL-OFF CALORIMETRY FOR HOT (150K) APPLICATIONS
- exotic liquids (Xenon @165K and Carbon Tetra-Fluoride CF4 @145K)
- complicated logistics
- health & occupational hazards
- limited accuracy and repeatability, especially for short cold fingers
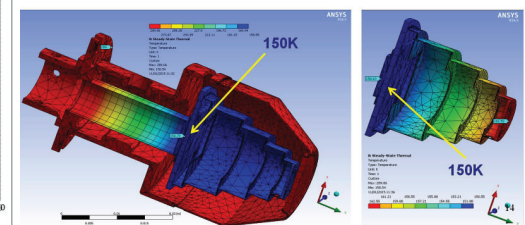
MOTIVATION
- accurate calorimetry at any temperature
- no exotic cryogenic liquids

EXPERIMENTATION

IDDA #1 — 100mW added — IDDA #2

IDDA #1: $y = 0.2031x + 144.58$, $R^2 = 0.9998$
IDDA #2: $y = 0.205x + 144.59$, $R^2 = 0.9998$

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FE MODELING @150K

150K

LN2 BOIL-OFF CALORIMETRY: PRACTICE AND LIMITATIONS

- LN2 boil-off calorimetry

*Heat load = (boil-off rate) x (latent heat of vaporization)*

Limitations:
- LN2 inside the cold finger - thermal short
- Flow rate – "last drop" boiling
- Explosive (geysering) boiling
- Residuals of gaseous N2 - convective and conductive losses
- Heating of N2 residuals inside tube: parasitic gas expansion
- Typical accuracy is 10%
- Not applicable for short cold fingers

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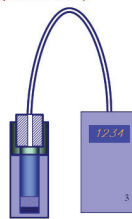
WARM-UP CALORIMETRY: BACKGROUND

Heat Fourier equation for the warm-up

$$C(T)\dot{T} = H_0(T) + H; \quad T \in [T_{init}, T_h], t > 0$$

$C(T)$ – aggregate heat capacity

$H_0(T)$ – aggregate parasitic heat inflow (conductivity, convection, radiation)

$T = T(t)$ – instant temperature

t – time

$\dot{T} = \dfrac{dT}{dt}$ – warm-up rate
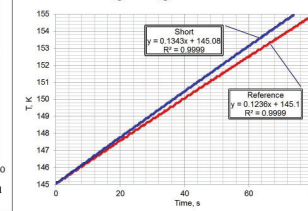
H - trial heat load

Warm-ups at different trial heat loads (mW)
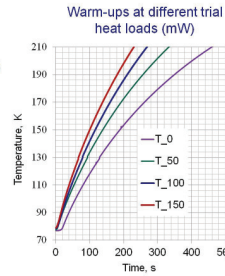
WARM UP RATES AT DIFFERENT ADDED HEAT LOADS

IDDA #1 — IDDA #2
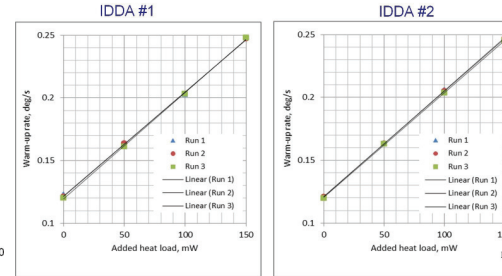
ACCURACY OF WARM-UP CALORIMETRY

- Calibrated Cu sprung ring L=6mm
- Effective 3.8mm thermal short
- Added heat load – H=12.5 mW@150K@20C

Short: $y = 0.1343x + 145.08$, $R^2 = 0.9999$

Reference: $y = 0.1236x + 145.1$, $R^2 = 0.9999$

$$H_0(T) = \frac{H}{T'(T)/T_0'(T) - 1} = \frac{0.0125}{\frac{0.1343}{0.1236} - 1} = 0.145W$$

BOIL-OFF CALORIMETRY: PRACTICE AND LIMITATIONS

BOIL-OFF STATION

Flow meter
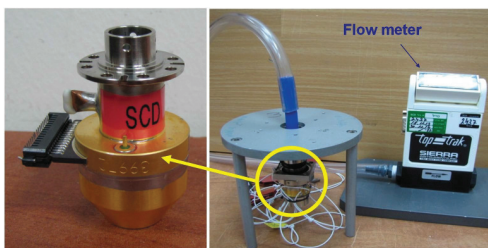
WARM-UP CALORIMETRY: BACKGROUND

Two warm-ups

$$C(T)T_0'(T) = H_0(T); \qquad C(T)T'(T) = H_0(T) + H$$

$$C(T) = \frac{H}{T'(T) - T_0'(T)}; \quad H_0(T) = \frac{H}{T'(T)/T_0'(T) - 1}.$$

- Accuracy of dual-slope calorimetry is not sufficient
- Novelty: multi-slope calorimetry

EVALUATION OF SELF HEAT LOAD

$$\dot{T} = aH + b$$
$$\dot{T} = 0; \quad H = -H_0$$
$$\Rightarrow -aH_0 + b = 0$$
$$\Rightarrow H_0 = \frac{b}{a}$$

Run #	Dewar #1			Dewar #2		
	a	b	H_0, mW	a	b	H_0, mW
1	0.000833	0.121375548	145.68	0.000841	0.121311	144.22
2	0.000833	0.121217626	145.55	0.000838	0.121301	144.75
3	0.000826	0.120200975	145.51	0.000835	0.120522	144.34
Average			145.58			144.44
Normalized STD			0.06%			0.2%

MULTI-SLOPE WARM-UP CALORIMETRY:

- Use of regular LN2
- Accuracy and repeatability are inherently high
  - thermometer and timer are more accurate than mass flowmeter
  - warm-up curve is very smooth and convenient for processing
  - test may be performed in vacuum
- May be performed at any FPA temperature
- Applicable in production of operational IDDAs