SPIRE & PACS Sorption Coolers SPIRE CQM – PERFORMANCE VERIFICATION

SBT internal ref : SBT/CT/2004-43

	Name & Function	Date	Signature
Prepared	L. Duband - Cooler project manager		
SBT PA Check	M. Dubois – Cooler PA manager		
SPIRE Approval	N/A		
PACS Approval	N/A		
PA Approval	N/A		
Project Approval	N/A		
Project Approval	L. Duband - Cooler project manager		

Service des Basses Températures (SBT)
Département de Recherche Fondamentale sur la Matière Condensée (DRFMC)
COMMISSARIAT A L'ENERGIE ATOMIQUE - GRENOBLE (CEA-Grenoble)
17, rue des Martyrs 38054 GRENOBLE Cédex 9, France.

Document Status

Issue	Revision	Date	Nb of pages	Modifications
0	0	June 21st 04		First draft
1	0	June 28th 04		First issue

Table of Contents

List of Acronyms

AD	Applicable Document		
CEA	Commissariat à l' Energie Atomique		
CDR	Critical Design Review	Revue de conception détaillée	RCD
CQM	Cryogenic Qualification Model		
EV	Evaporator		
FIRST	Far Infrared and SubmillimetreTelescope		
FS	Flight spare		
HSE	Heat Switch (on evaporator)		
HSP	Heat Switch (on sorption pump)		
N/A	Not Applicable		
PACS	Photoconductor. Array Camera and Spectrometer		
PFM	ProtoFlight Model		
RD	Reference Document		
SAp	Service d'Astrophysique		
SBT	Service des Basses Températures		
SCO	Sorption Cooler (full unit)		
SP	Sorption pump		
SPIRE	Spectral & Photometric Imaging Receiver		
SST	Support Structure		
TS	Thermal Shunt		
TSES	Thermal Strap to Evaporator Switch		
TSPS	Thermal Strap to Pump Switch		

1 Scope of the document

The SPIRE CQM sorption cooler, delivered to RAL in December 2004, has been integrated in the SPIRE instrument. The instrument went through thermal tests followed by vibration tests. The vibration tests were performed at low temperature.
The SPIRE project has then decided to send back the cooler to CEA-SBT for a performance verification (health check).
This note summarizes the various results obtained.
The Health Check Report sheet is also included at the end of the document.

2 Documents

2.1 Applicable documents

N/A

2.2 Reference documents

	Title	*Reference*
RD01	SPIRE and PACS Sorption Coolers – SPIRE CQM Tests report	HSO-SBT-RP-085
RD02	SPIRE and PACS Sorption Coolers – Hold time anomaly - Analysis	HSO-SBT-TN-091

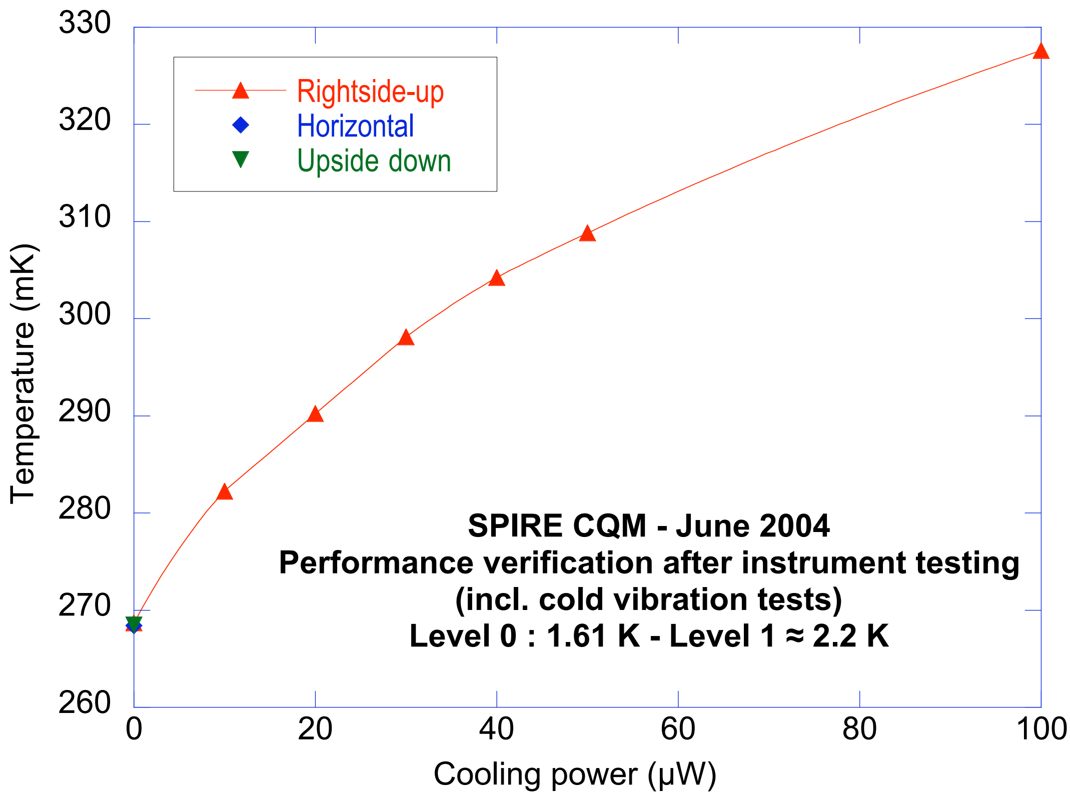
3 Thermal results

The cooler was integrated in the test cryostat CRYOTEDI III (see RD1 and RD2). The following set of tests have been carried out :

- cryostat pumped down to its ultimate temperature. Level 0 and Level 1 at their "natural" temperature (no regulation) :
  - ultimate temperature in the rightside-up, horizontal and upside down position
  - rightside up position : cooling power curve
- Level 0 interface (heat switch evaporator) regulated at 1.7 K, and Level 1 (structure) regulated at 4 K :
  - Autonomy tests under various load

3.1 Cooling power

No particular problem was spotted during the various cooler recycling. The cooling power curve is displayed in the following graph.

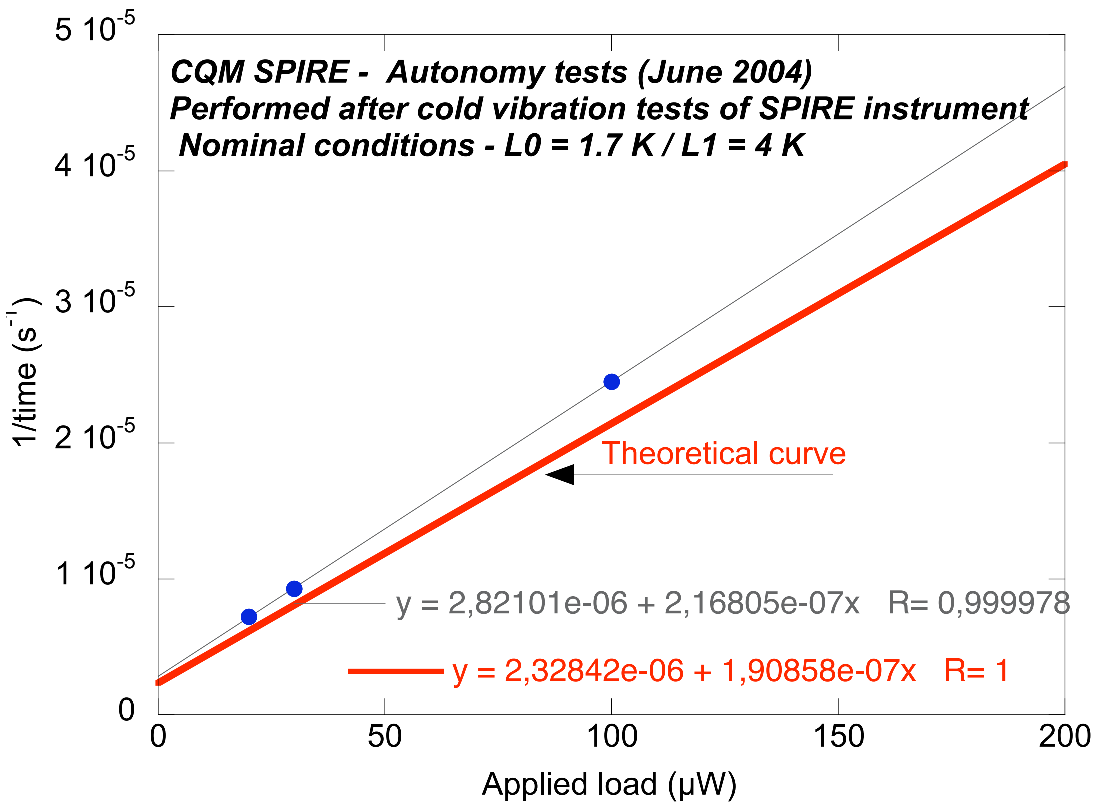


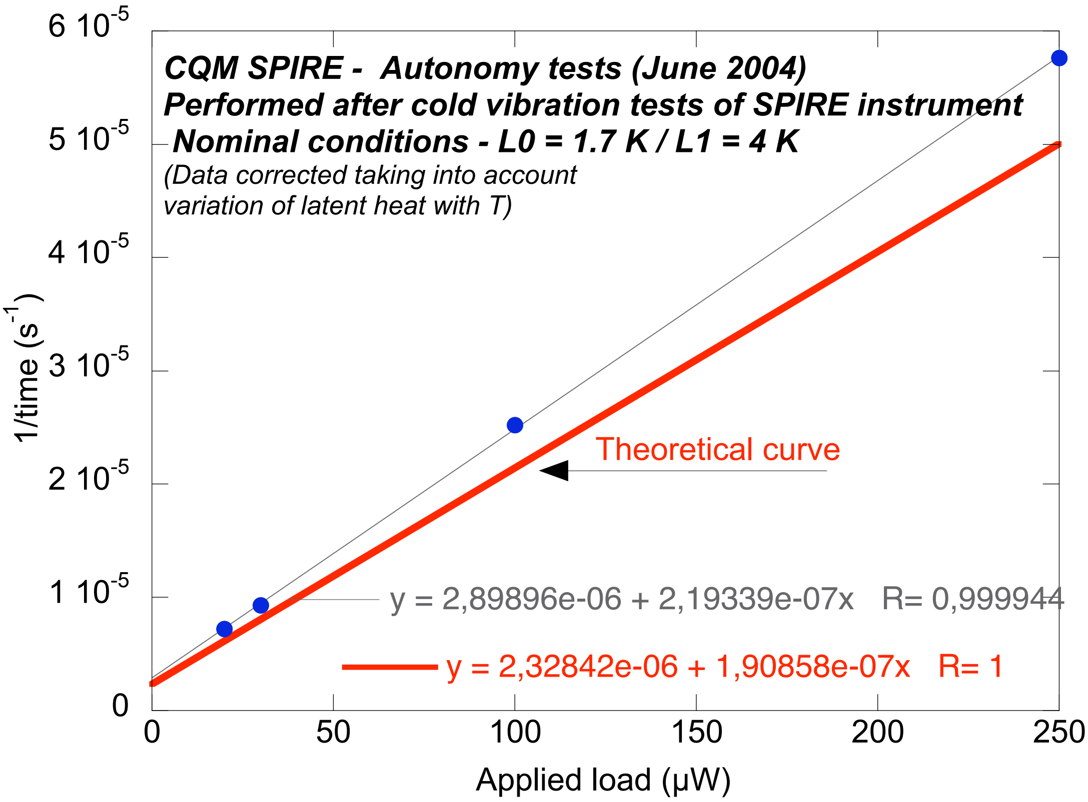
The results are consistent with previous measurement on the cooler, and the performance remain unchanged whether the cooler is operated rightside-up, horizontal or upside-down.
During a subsequent test the cooler was left overnight operating at its ultimate temperature (no applied load). For a cryostat cold plate of 1.6 K and a structure at 1.86 K, the ultimate temperature with the cooler rightside up (tilted at 60°) was found to be 263 mK.

3.2 Autonomy tests

The autonomy of the cooler was then measured for various applied loads. These tests were all done in the same initial thermodynamic conditions, a condensation at 2.1 K at the evaporator and a sorption pump temperature of 45 K. One can then assume the amount of liquid at ≈ 300 mK at the beginning of the low temperature phase is the same for each experiment carried out. In addition the operating temperatures are close enough the latent heat (L) can be considered constant (yet we have also reported the corrected results taking into account the variation of the latent heat). We can then simply write the amount of "cold" joules produced is equal to the total load times the autonomy : m_0 x L = ($P_{applied}$ + $P_{parasitics}$) x time (where m_0 is quantity of liquid at the beginning of the low temperature phase).
Plotting 1/time versus $P_{applied}$ should then give a curve of slope 1/(m_0 x L) and of ordinate $P_{parasitics}$ /(m_0 x L).
This analysis is reported on the following curves and is summarized in the tables hereafter.

T condens. (K) (evaporator)	*T pump (K)*	*Applied load (µW)*	*Ultimate T (mK)*	*Hold time*
2.06	44.2	20	289	38 h 30 mn
2.2	45	30	296	30 h
2.08	44	100	327	11 h 08 mn
2.12	43.2	250	361	5 h 4 mn





Note : theoretical curve calculated assuming 100% nominal charge

Data	***Parasitics experimental***	***Parasitics predicted***	***Ratio m_0/m_{total} experimental***	***Ratio m_0/m_{total} predicted***
Raw	13 µW	11.5 µW	66%	72%
Corrected	13.2 µW	11.5 µW	65%	72%

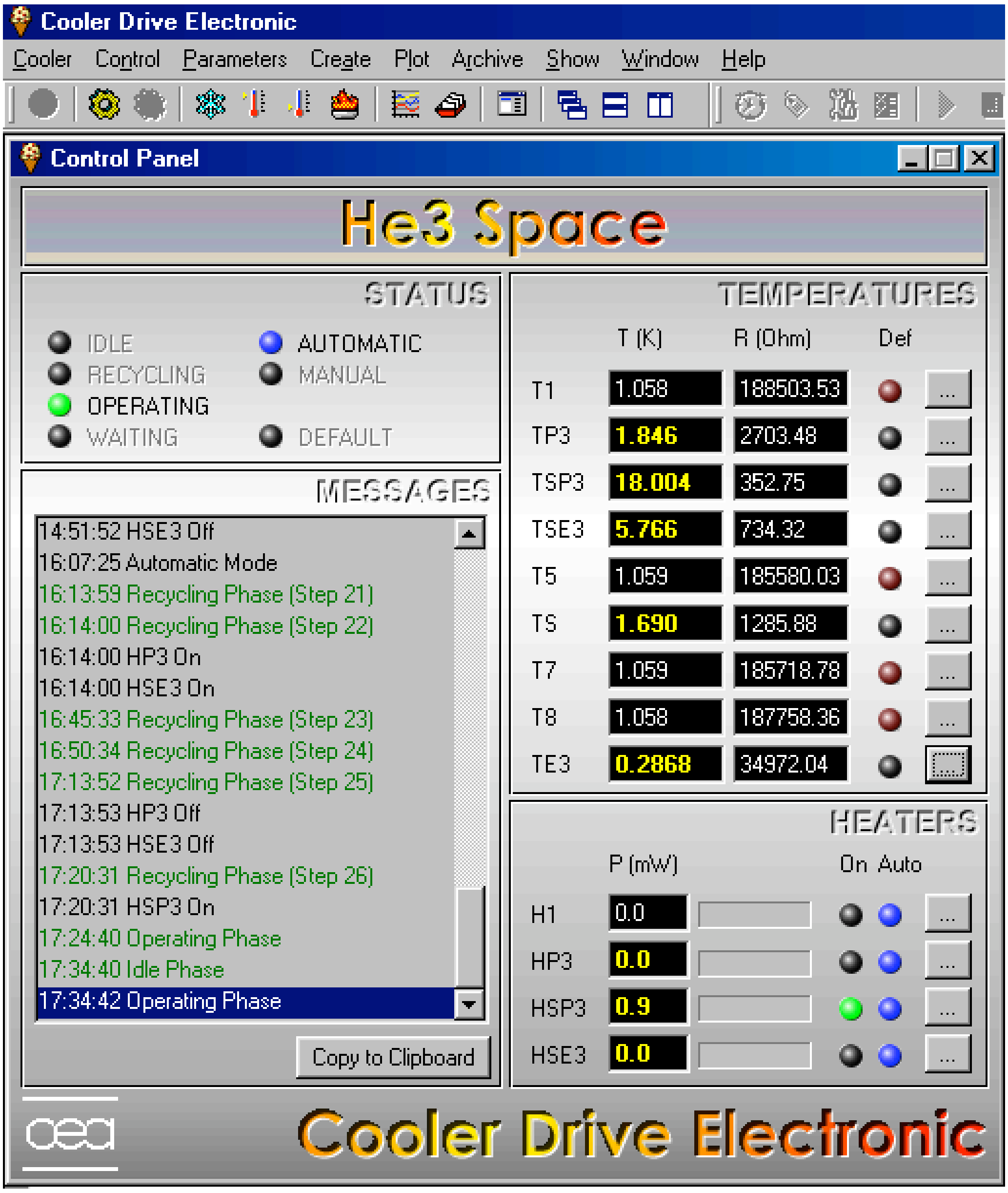
Obviously the results indicate as before the cooler is undercharged by about 10%.
The parasitic load extracted from the experimental data is pretty much consistent with prediction; the 1.5 µW excess is within the uncertainties (from calculations and experimental conditions (radiative load)). Assuming the cooler is undercharged by 10%, we have reported in the table below the measured and the predicted hold time.

Applied load (µW)	***Ultimate T (mK)***	***Hold time Experimental***	***Hold time Predicted***
20	289	38 h 30 mn	38 h 47 mn
30	296	30 h	29 h 32 mn
100	327	11 h 08 mn	11 h 8 mn
250	361	5 h 4 mn	4 h 48 mn

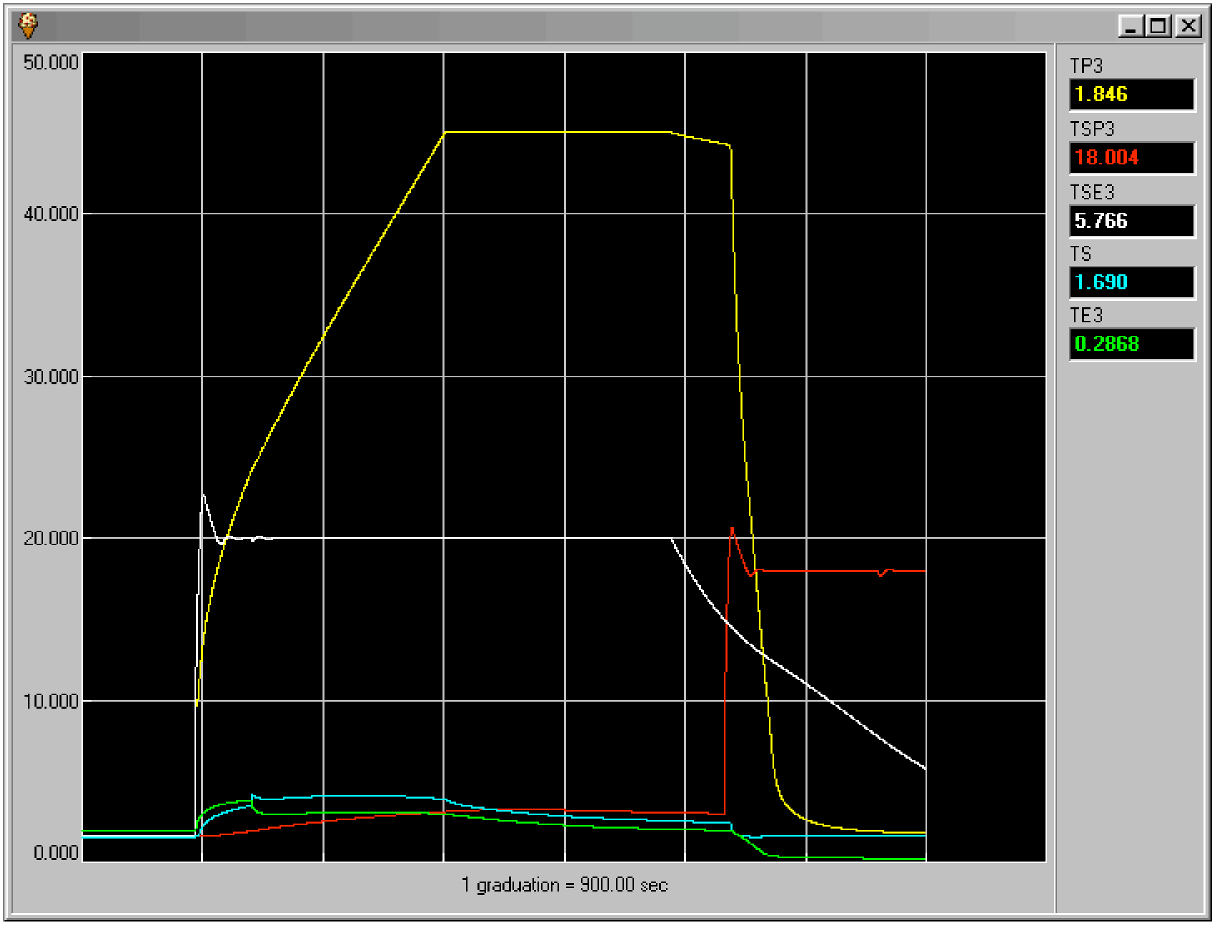
The predicted and experimental hold time match fairly well.

3.3 Test of the Cooler Drive Electronic (CDE)

A laboratory drive electronic (CDE) has been developed by CEA-SBT for the cooler operation. A prototype of this electronic has been delivered to RAL.
The CDE features the same algorithm developed by CEA-SBT for the space version of the flight electronic (SAp). It thus interesting to check whether this algorithm allow for efficient cooler recycling and operation. The tests carried out have proven to be successful. The following set of pictures show the CDE display and a typical recycling.



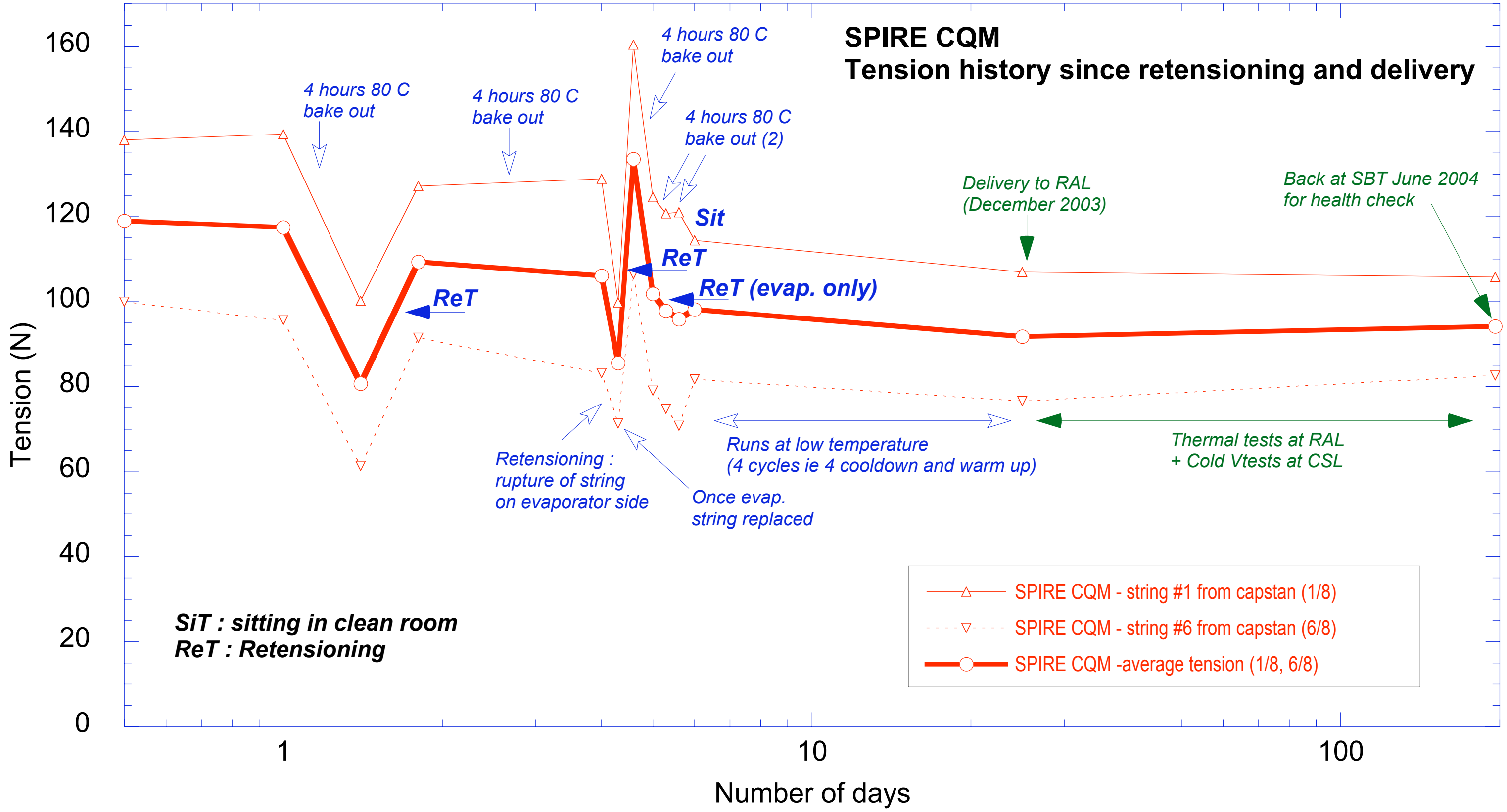
CDE display overview



Typical recycling (fully automatic)

3.4 Kevlar tension history

The tension in the external Kevlar string (sorption pump side) has been measured. The tension history since delivery, shown on the following figure, indicates the tension has not been affected by the various thermal cycling and environmental tests. The new tensioning procedure used for this unit is satisfactory.



4 Conclusion

The performance of the SPIRE CQM unit have been checked and found to be satisfactory and consistent with prediction. The performance were verified after the CQM unit had been integrated in the SPIRE instrument, had underwent thermal tests and vibration tests (including a vibration test at low temperature).

It is reminded the SPIRE unit was initially delivered to RAL in December 2003 with a new strap material : thin copper wires, not braided, ultra flexible, same section and mass as the original one (see RD02). This new set of results further qualify the use of this strap since thermal as well as environmental tests have been carried out on the cooler.

Of course the results indicate again the cooler is undercharged by roughly 10%. This problem is regarded as minor : a new filling procedure has been discussed which will allow to charge (or overcharged if necessary) the flight coolers to the nominal helium load.

The tension in the Kevlar suspension system was checked on the sorption side, external string. The measured tension shows almost no variation of tension since the delivery in December 2003. This result is crucial as the CQM unit was retensioned over 6 months ago prior to delivery using the new procedure established to stabilize the Kevlar strings (problem of creep under tension and thermal cycling). This new procedure is consequently validated.

5 Appendix

SPIRE & PACS Sorption Coolers

HEALTH CHECK REPORT (HCR)

Référence :

HCR#5 SPIRE

Référence cryoréfrigérateur : ***Sorption Cooler CQM Ref.: 2000-14 B 000 S/N : 1***

Raison du contrôle :

Vérification des performances après tests thermiques et tests vibratoires de l'instrument SPIRE (Cooler CQM démonté de l'instrument et renvoyé au CEA-SBT)

Date : Juin 2004
Nom : L. CLERC / L. DUBAND
Signature :

Contrôle mécanique / électrique Visuel : R.A.S

Tension des brins Kevlar

Coté pompe : *avant test 105.8 (1/8) /82.6 (6/8) – après :* Coté évaporateur : N/A

Contrôle impédance thermomètres (T) et chauffages (C) (à T ambiante, et comprenant les fils de mesures)

(indiquer pour chaque composants les valeurs en Ohm prises au connecteur principal (P) et redondé (R))

T pompe	C pompe	T inter P	C inter. P	T évaporat.	T inter évap.	C inter évap.	T shunt
52.4/46.8	*407.2/407.5*	*50.9/45.2*	*407.6/414.3*	*45.8/50*	*48.6/-*	*407.2/407.1*	*46/47*

Rapport : *conformes.*

Contrôle de fuite Référence détecteur : ALCATEL ASM 180

Valeur de fuite mesurée (après): *7 10^{-10} mB/l.s* Commentaires : R.A.S

Contrôle thermique

Cycle A – *Phase de condensation :*

T bain ^{4}He	T structure	T pompe/Puiss.	T évaporateur	T inter P	T inter E/Puiss.	T shunt
1.65	*2.8*	*45 / 300*	*2.1*	-	*20 / 0.8 mW*	*2.46*

Phase basse température – T bain : 1.62

Orientation	+90° (Endroit)	0° (Horizontal)	- 90° (Envers)	Commentaires :
T mini (mK)	*268.7*	*268.4*	*268.5*	

Courbe de puissance (Orientation : vertical endroit)

Charge (µW)	0 (Tmini)	10	20	30	40	50	100
T (mK)	*268.7*	*282.2*	*290.2*	*298.1*	*304.2*	*308.8*	*327.6*

Cycle B – *Phase de condensation :*

T bain ^{4}He	T structure	T pompe/Puiss.	T évaporateur	T inter P	T inter E/Puiss.	T shunt
2.1	*2.81*	*45.5 /300 mW*	*2.12*	-	*20 / 0.8 mW*	*2.6*

Phase basse température *– T bain : 1.6, Interface regulée à 1.7 K et Structure régulée à 4 K*

Autonomie et température sous 20 µW de charge appliquée : *38h30 @ 289 mK*
30 µW : 30h @ 296 mK, 100 µW : 11h08 @ 327 mK et 250 µW : 5h04 @ 361 mK

Conformité *OUI* ~~*NON*~~

RAPPORT :

Hormis le défaut de remplissage (déjà trace et à corriger sur FM), les performances obtenues sont satisfaisantes. Les pertes parasites mesurées sont conformes aux prédictions. Ces tests contribuent à valider la "nouvelle" strap évaporateur

Visa Projet **-** Nom, date et signature : *Lionel DUBAND – 28 Juin 2004*