SAFT VES180 High Specific Energy Cell Qualification

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Photos D.R.

Agenda

- **Development Program**
- **QM Cell Results**
- **Life test Plan**
- **Conclusion**

Introduction

- 1996, Start of the development of the first Li-Ion battery for Stentor GEO satellite
- 2002, First Orders for Li-Ion batteries for big GEO satcoms and LEO satellites
- 2003 : Launch of Smart1
- 2004 : Launch of W3A and Amazonas
- 2005 : Launch of Syracuse 3A

Introduction

- **Li-Ion is now a reality for GEO communication satellites**
- **The 4 seasons experience in orbit with W3A (and 3 with Amazonas) are in line with the original life predictions.**
- **All the previously out-lined Li-Ion advantages (vs NiH2) have been confirmed :**
  - Weight saving
  - Thermal dissipation
  - Self-discharge
  - Energy efficiency
  - Energy gauge
  - Etc.

Introduction

- **The VES140 minimum guaranteed specific energy is 125 Wh/kg**
- **Saft has started at the beginning of 2003 a development and qualification of the “high specific energy” cell (target 170 Wh/kg).**
- **ESA and CNES support this qualification in the frame of Alphabus program : ARTES8**

Main Objectives for VES180

- **Increase of the specific energy**
- **Increase of the charge rate capability**
- **Same interface as per VES140 to stay with same battery configuration**
- **Qualification for AlphaBus satellite**

VES180 Development Program

- **Program :**
  - Phase 1 : Preliminary design
  - Phase 2 : CDR and qualification
- **Key Dates :**
  - KO : 14 January 03
  - PDR : 5 December 03
  - CDR mechanical part : 8 December 04
  - CDR : 25 May 05
  - QR : Dec 05

VES180 Performances

- **Cell Specification :**
  - Energy : 180 Wh @ EOCV=4.1 V
  - Specific Energy : 170 Wh/kg @ EOCV=4.1 V, 30 °C
  - Fading + Calendar : same as VES140 (<5% for 15 years)
  - Mid Voltage : 3.6 V
  - Voltage limits : 2.7 to 4.1 V
  - Temperature range : 0 to 40 °C
  - Vibrations : compatible with all launchers profiles
  - Leak rate : 10-7 cm3.atm/s

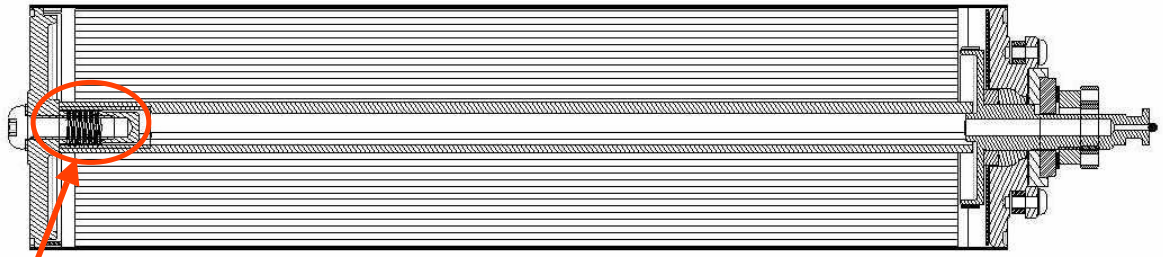
Changes vs VES140

	Parameter	Change from VES140
Positive Electrode	**Active material** **Binder**	▪Thickness ▪Loading ▪Composition ▪ Percentage
Negative Electrode	**Graphite** **Binder**	▪Type of material ▪Thickness ▪Porosity ▪Type ▪Ratio
Electrolyte	**Additive**	▪Percentage
Separator	**None**	

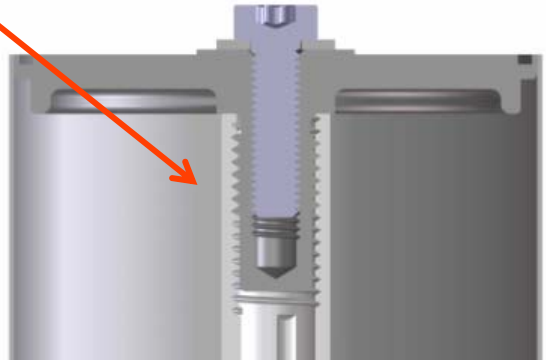
- **External Mechanical Interface unchanged vs VES140**

Mechanical change vs VES140

- **In order to sustain higher vibration levels : up to 25 g sine and 17 gRMS random at battery side**



Change VES140S vs VES180S



Manufacturing capability

- **VES180 manufactured on the same industrial line as per VES140 :**
  - same equipments and machines :
    - mixing
    - Coating line
    - calendaring
    - Rolling machine
  - capability > 15 000 cells per year
- **60 000 cells manufactured since 1999**

Coating Line

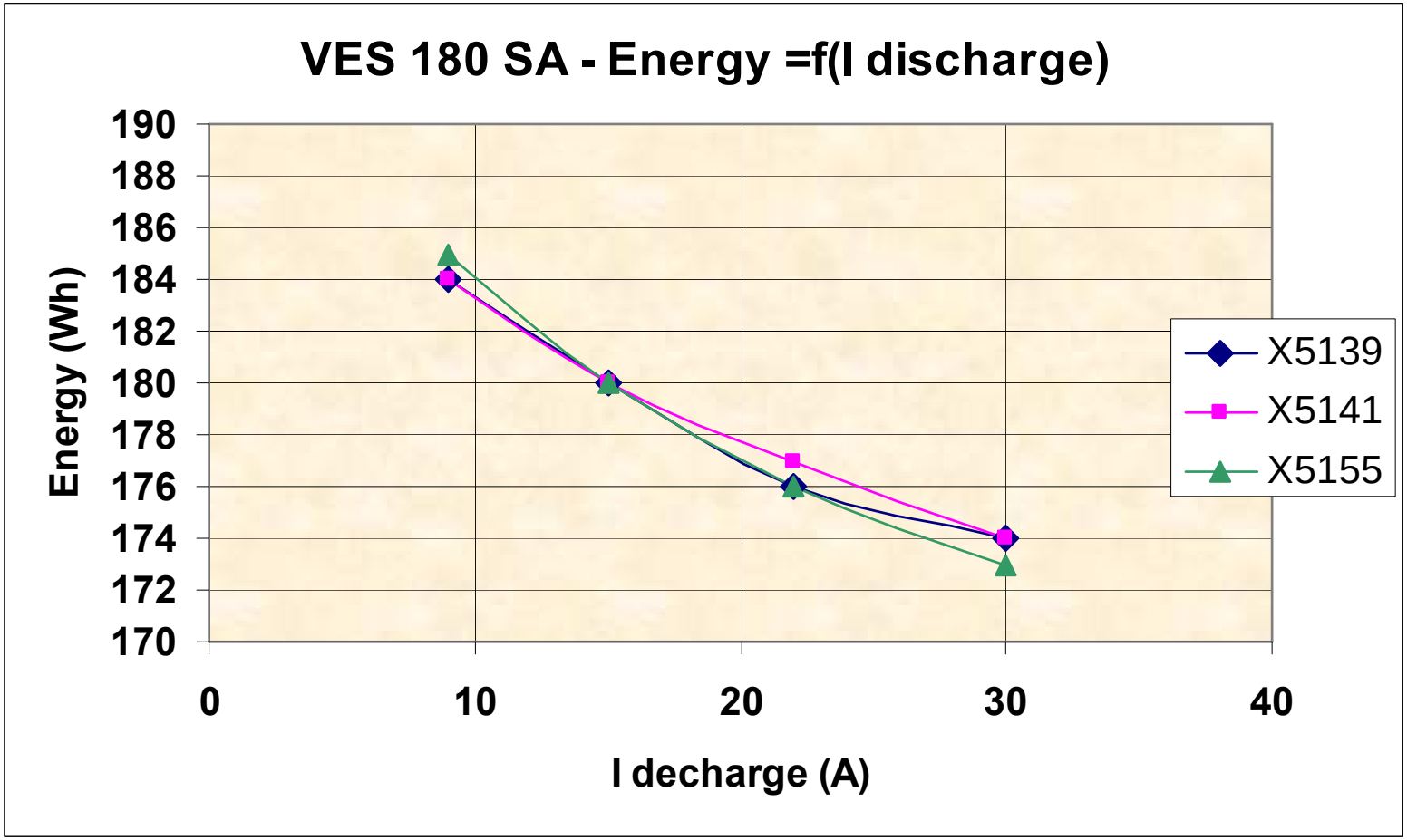
Rolling

VES180 first lots

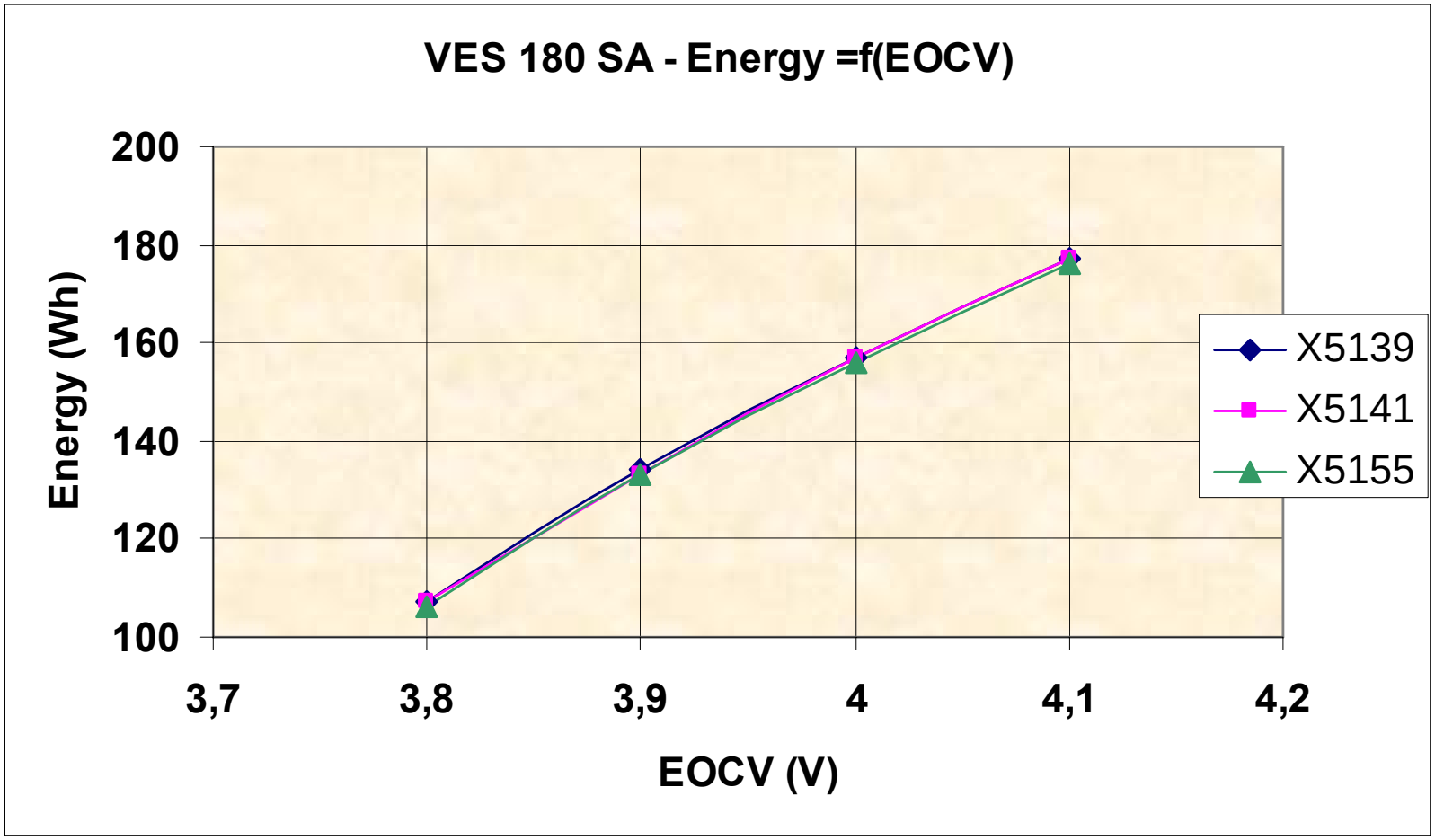
- **12 EM Cells**
- **120 cells have been manufactured (5 lots) including 15 QM cells :**
  - Electrical tests
  - Mechanical tests (battery configuration)
  - Abuse tests
  - Life tests

EM cells : Energy vs discharged current

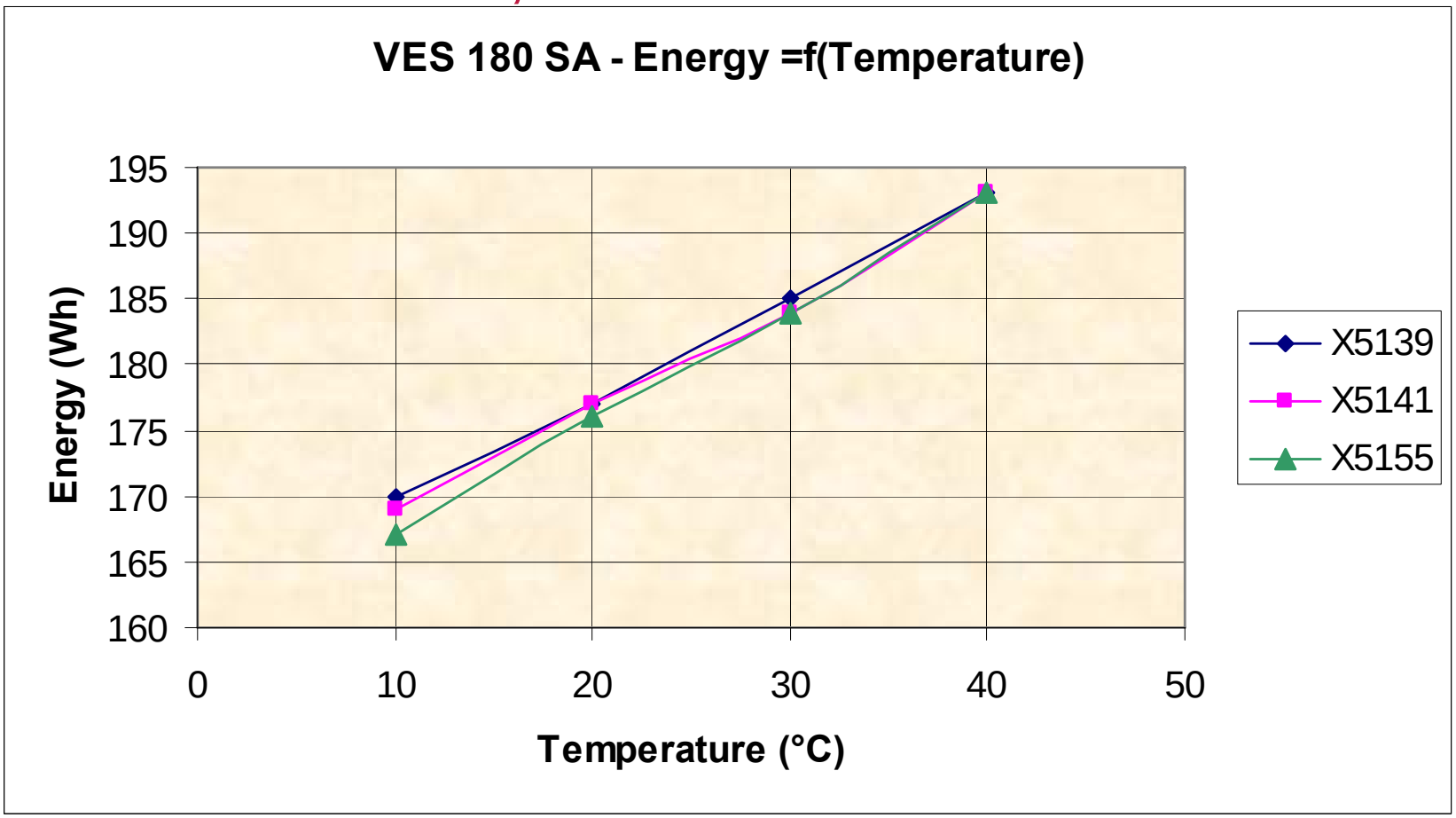
EOC @4.1V T=20 °C



EM Cells : Energy vs EOCV @20 °C, C/1.5



EM cells : Energy vs temperature EOCV=4.1V, C/1.5



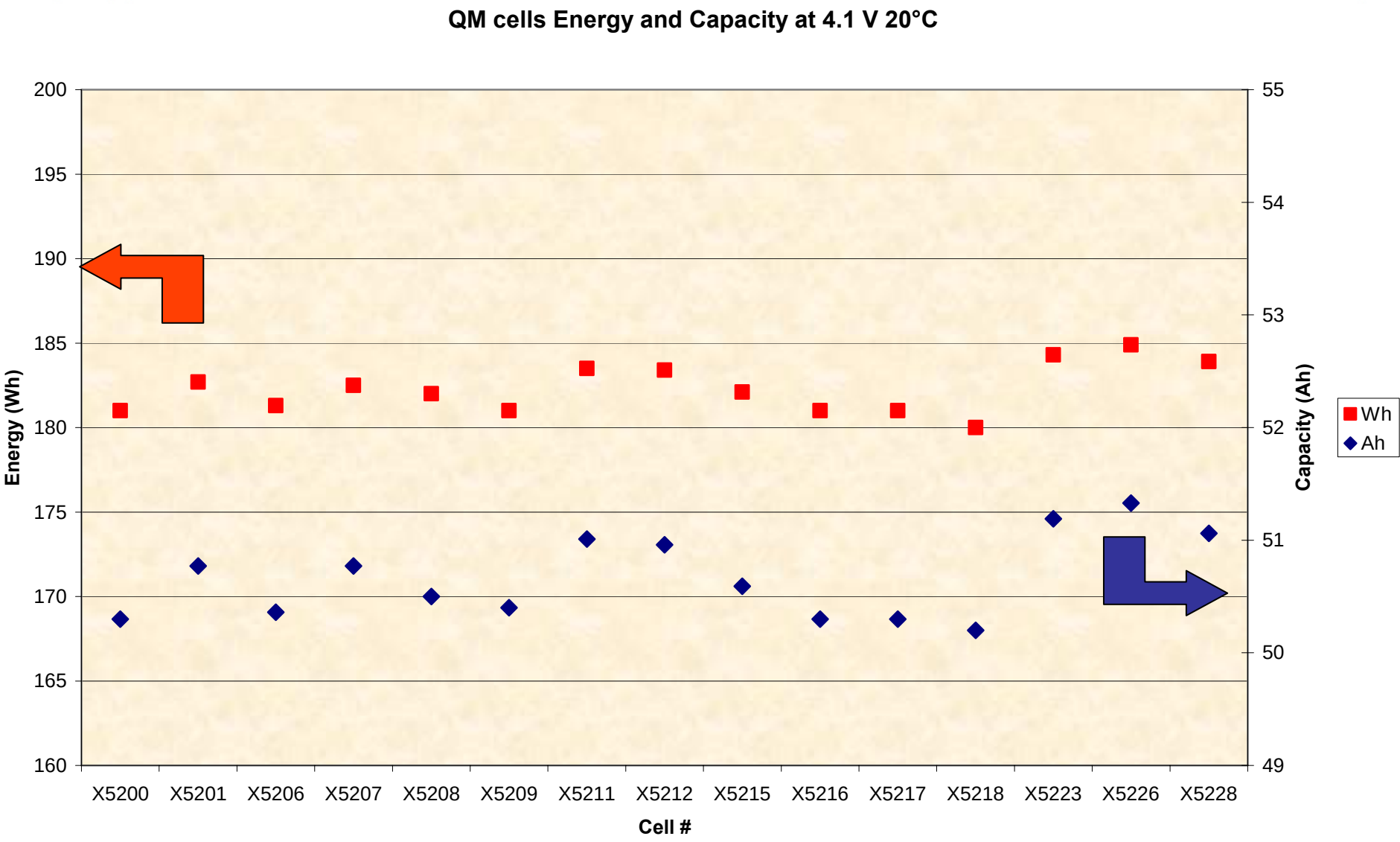
Qualification test plan : electrical

Test designation	Test condition	VES 180 SA QM cells														
		QM-cell1	QM-cell2	QM-cell3	QM-cell4	QM-cell5	QM-cell6	QM-CP1 – cell1	QM-CP1 – cell2	QM-CP1 – cell3	QM-M1 – cell1	QM-M1 – cell2	QM-M1 – cell3	QM-M1 – cell4	QM-M1 – cell5	QM-M1 – cell6
Acceptance test																
Pressure test	Done on each Welding lot during manufacturing															
Acceptance tests	Visual inspection, mass, identification Energy, internal resistance, leakage current @20°C	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Functional electrical tests																
Capacity / energy / Internal resistance REFERENCE TEST	20°C – discharge current C/2 EOCV 4.1V - EOCV 4.1V	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Charge retention	3.5 V – 72 h – 20°C	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Capacity / energy – current influence	20°C – discharge current C/1.5 – C/3 – C/5 - EOCV 4.1V	4	4	4	4	4	4									
Capacity / energy / Internal resistance - temperature influence	10°C, 30°C, 40°C, 50°C and 0°C discharge current C/2 - EOCV 4.1V	6	6	6	6	6	6									
Constant Power Energy	20°C - EOCV 4.1V 165W, 110W, 83W, 33W	5	5	5	5	5	5									
Self discharge	1 month – EOCV 4.1 V, 3.5 V															
Impedance (@ 20°C)		7	7	7	7	7	7									
pulse		8	8	8												
Thermal Model correlation	Thermal capacity / thermal gradient / heat dissipation measurement in thermal vacuum chamber				8											
Environment																
Temperature exposure	24 hours 60°C					8	8									
Thermal vacuum cycling	Ref. cycle 10 cycles - 20°C / +50°C Ref cycle					9	9									
final test (Capacity / energy + Internal resistance)	20°C – discharge current C/2	9	9	9	9	10	10									
Final test (Charge retention)		10	10	10	10	11	11									

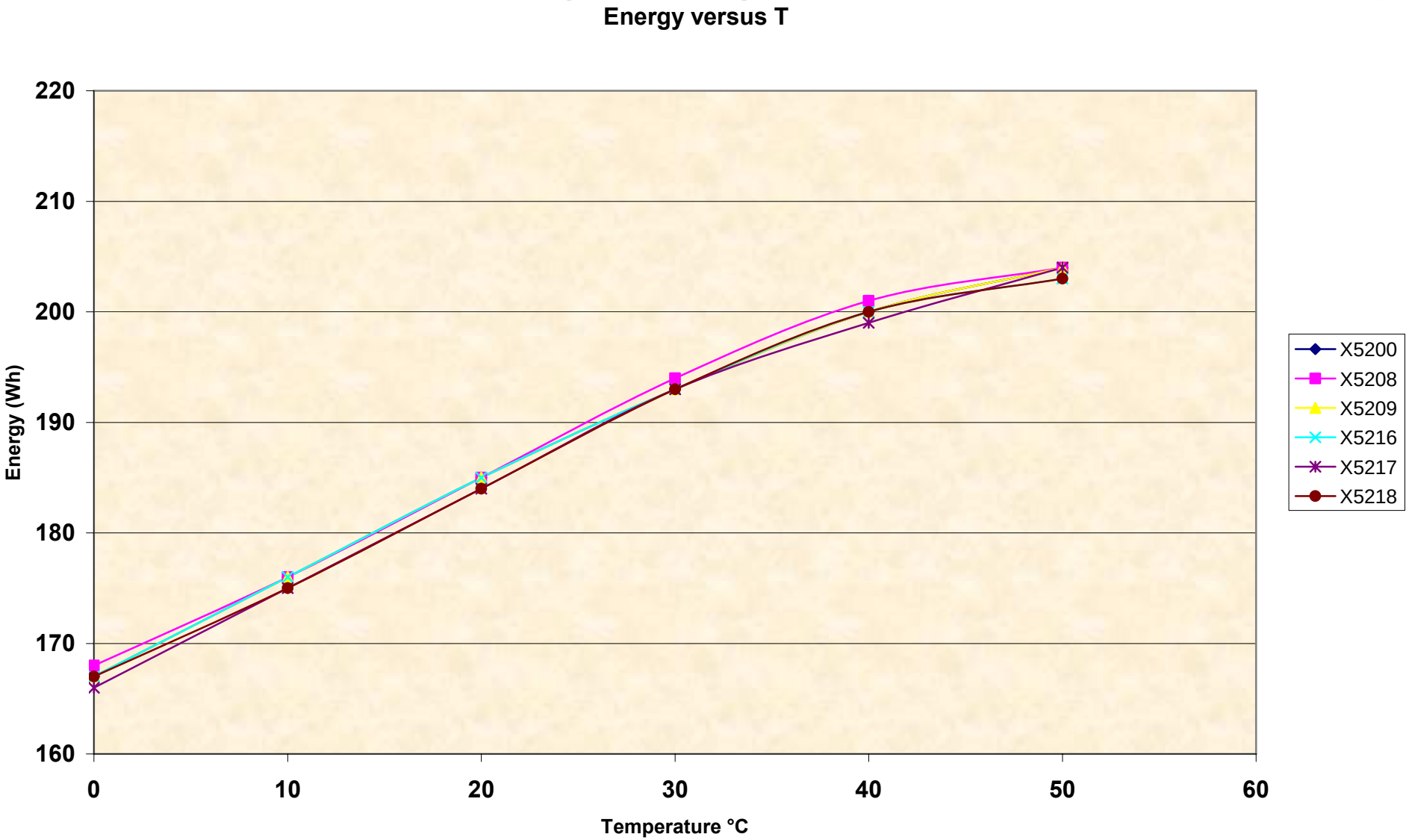
Qualification test plan : mechanical part

	Mechanical tests																
	Initial X RAY picture								4	4	4	4	4	4	4	4	4
	Sine vibrations test on OX-OY-OZ	EOCV > 3.9V							5	5	5	5	5	5	5	5	5
	Random vibrations on OX -OY- OZ axis	EOCV > 3.9V							6	6	6	6	6	6	6	6	6
	Check up (capacity / energy + internal resistance after sine & random vibrations tests)	20°C – discharge current C/2 - EOCV 4.1V							7	7	7	7	7	7	7	7	7
	SHOCK	3.6 V > EOCV > 3.5 V										8	8	8	8	8	8
	Constant Acceleration	7.5 g-3 min. - EOCV > 3.9V							8	8	8						
	final test (Capacity / energy + Internal resistance) – after vibration tests	20°C – discharge current C/2							9	9	9	9	9	9	9	9	9
	Charge retention	3.5 V – 72 h – 20°C							10	10	10	10	10	10	10	10	10
	Final X ray picture								11	11	11	11	11	11	11	11	11
	Screw torque measure								12	12	12	12	12	12	12	12	12
	Destructive Physical Analysis (D.P.A)								13	13	13	13	13	13	13	13	13
	Abusive																
1	Overcharge 4.5 V						12										
2	Short circuit test	4 mOhm						12									
3	Over-discharge / Reversal		11	11	11												

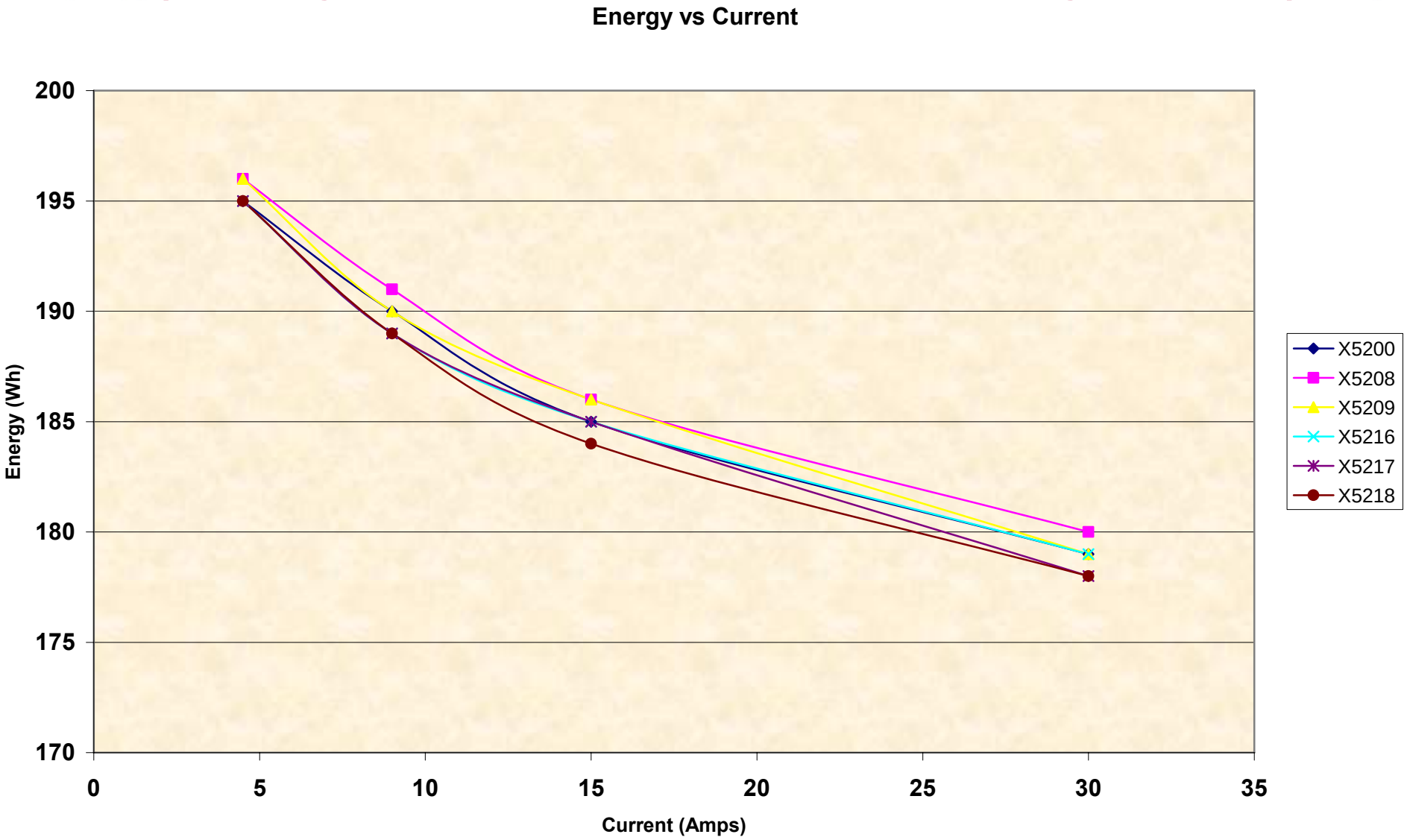
QM Results : energy at 4.1 V



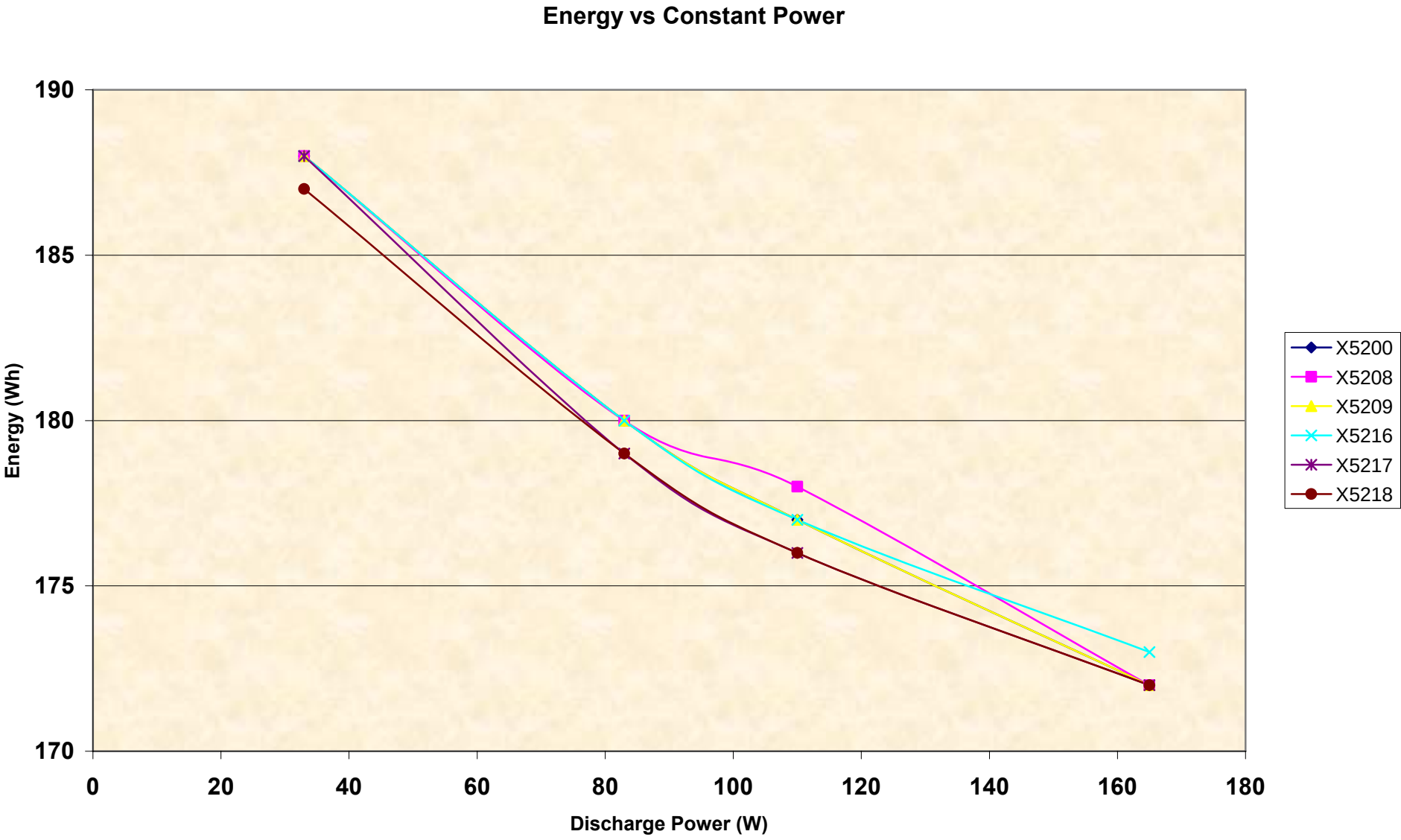
QM tests : Energy vs T (charge : @4.1 V C/10, Discharge C/2)



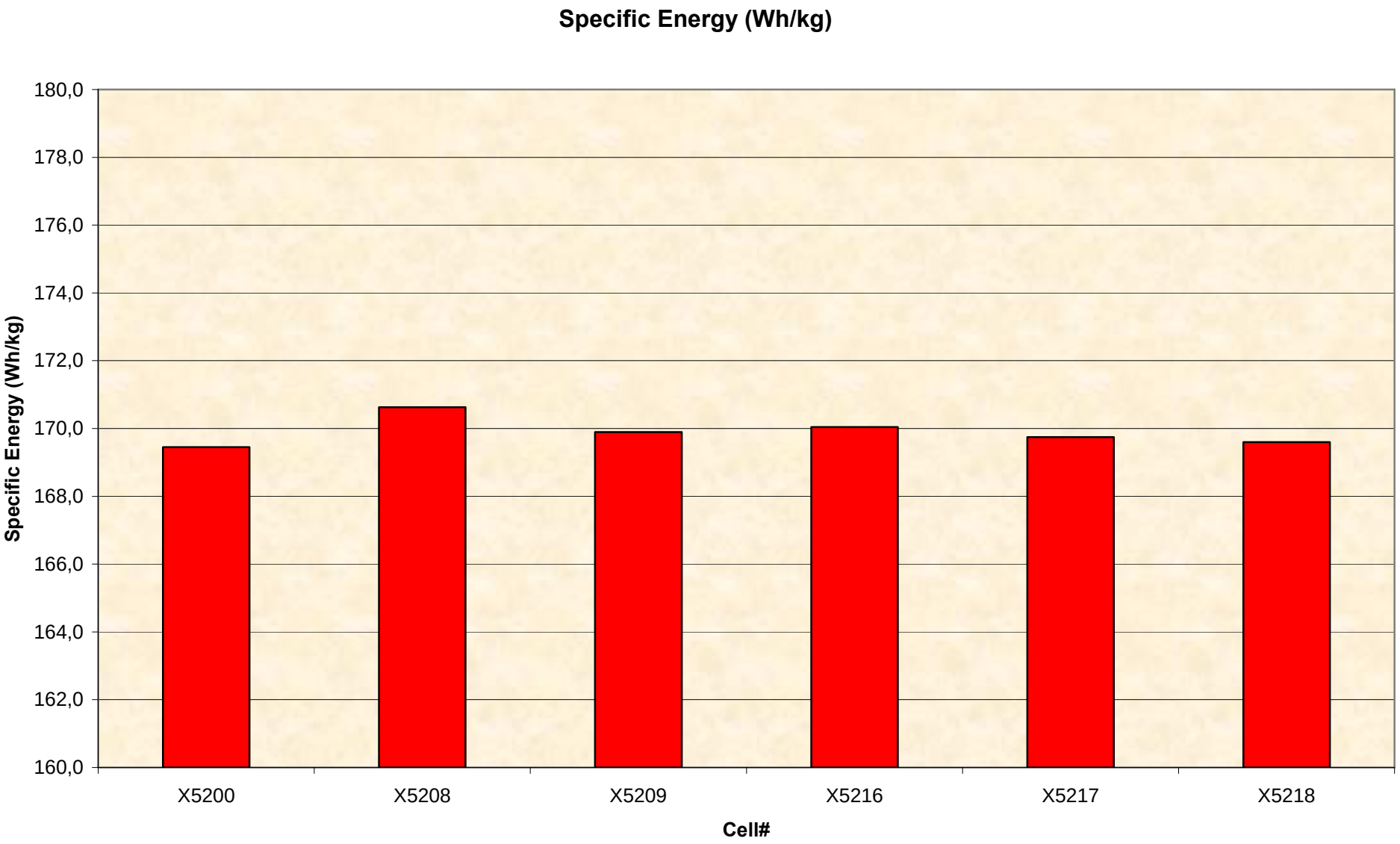
QM tests : Energy vs Discharge current (charge : @4.1 V C/10, Discharge 20°C)



QM tests : Energy vs P (charge : @4.1 V C/10, Discharge constant P 20°C)



QM tests : Specific Energy



Mechanical on QM cells

- **Mechanical tests performed on 3P and 6P modules :**

- **Sine levels**

Sweep rate: 2 oct/min per axis	Frequencies (Hz)	Levels
// to the mounting plane (X-Y)	5 –20	± 10 mm
⊥ to the mounting plane (Z)	20 – 55	20 g
(cell axis)	55 - 70	25g
	70 - 100	20g

Mechanical on EM cells

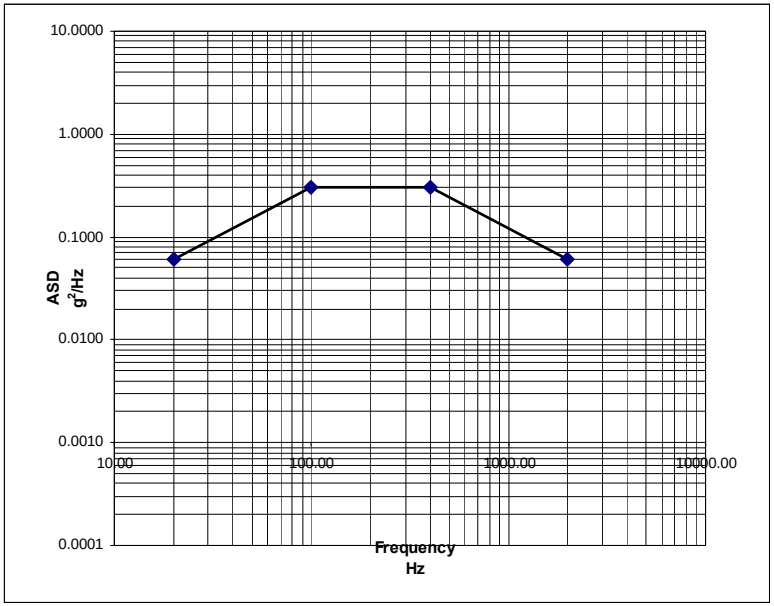
- **Random on 3P and 6P modules : 17.25 gRMS in Z**

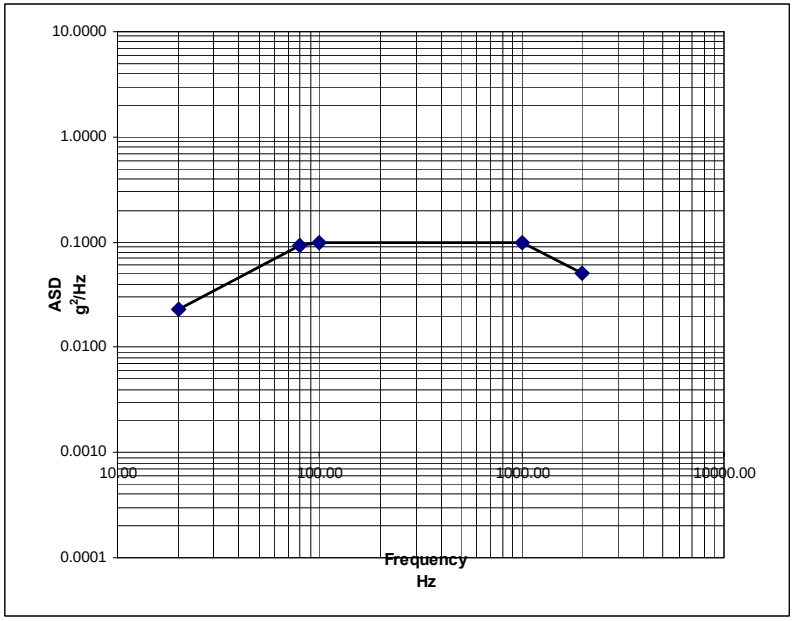
On OZ :

	Frequencies (Hz)	Levels	g RMS (g)
⊥ to the mounting plane (Z) 3 min	20-100	+3dB/oct	17.25
	100-400	0.3g²/Hz	
	400-2000	-3dB/oct	

On Ox - OY

	Frequencies (Hz)	Levels	g RMS (g)
// to the mounting plane (X-Y) 3 min	20-80	+3dB/oct	12.83
	80-100	0.093g²/Hz	
	100-1000	0.1g²/Hz	
	1000-2000	-3dB/oct	





Energy check after vibrations

	Before	After	Difference
X5201	183	180	-1,5%
X5206	181	180	-0,7%
X5207	183	180	-1,4%
X5211	184	181	-1,4%
X5212	183	181	-1,3%
X5215	182	181	-0,6%
X5223	184	183	-0,7%
X5228	184	182	-1,0%

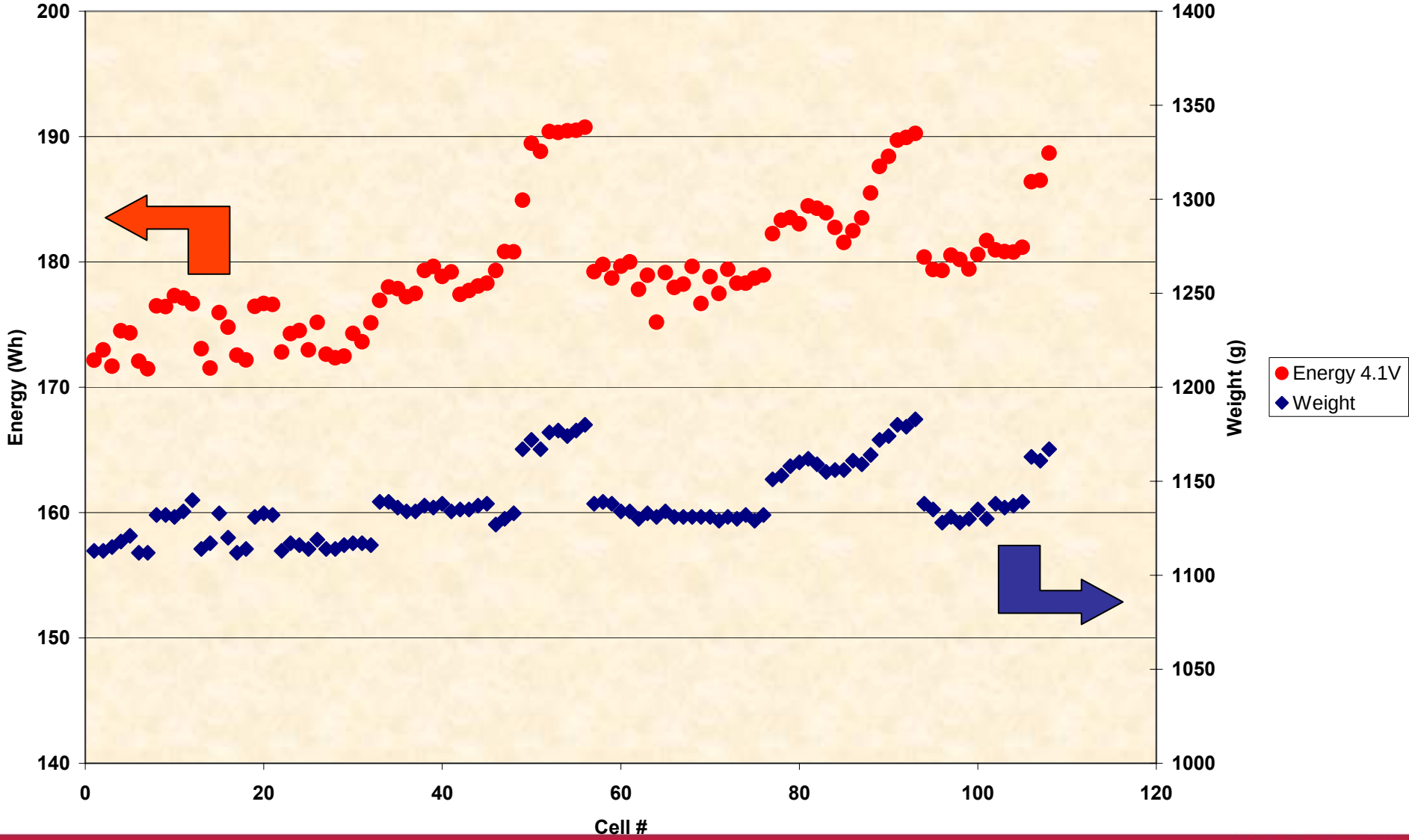
- **Criteria < 3%**

Acceptance Results

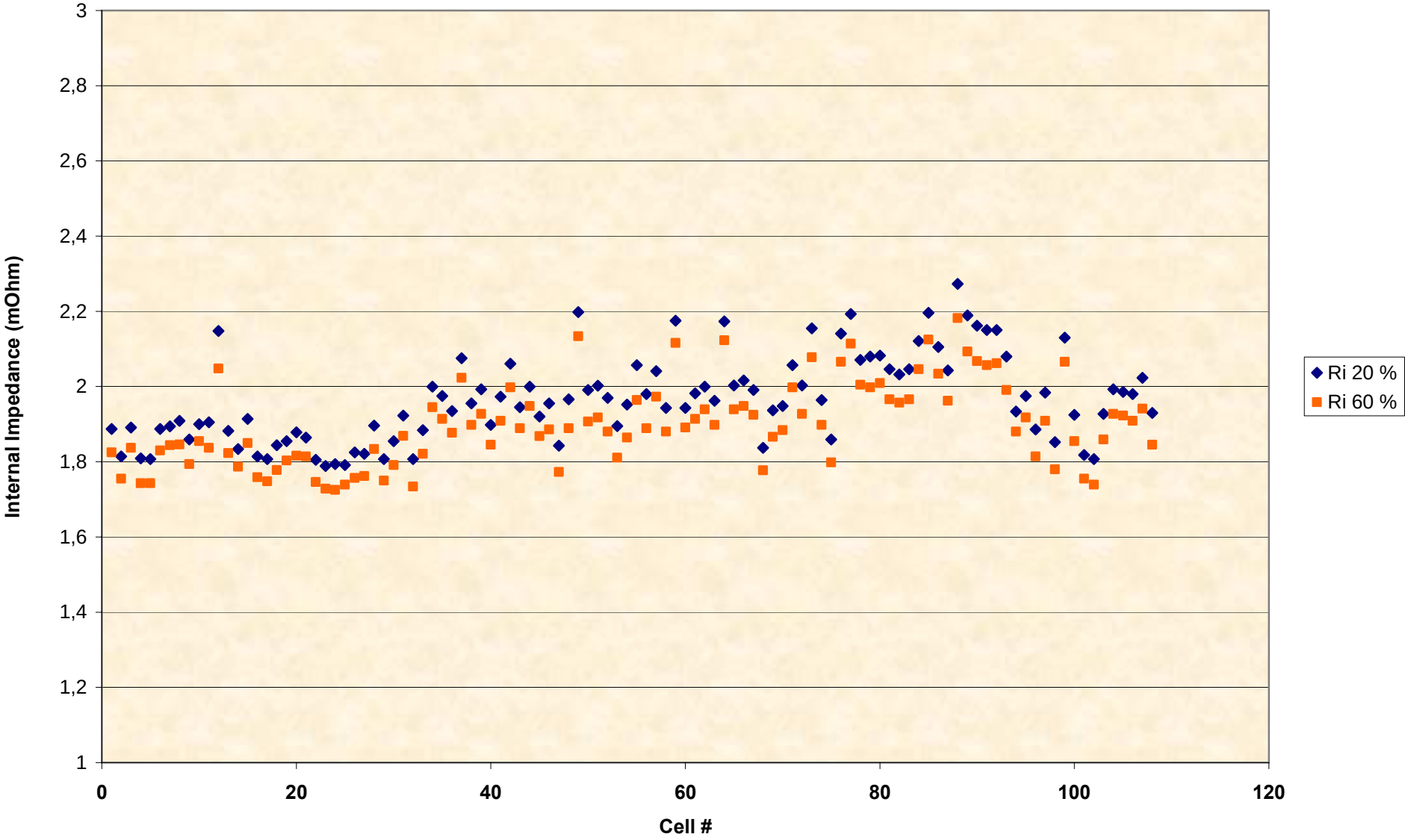
- **120 cells**
- **5 lots**

	Energie 4V Wh	Energie 4.1V Wh	Ri 20 % mΩ	Ri 60 % mΩ	Masse g
Average	161,75	179,54	1,97	1,90	1138,3
Min	154,47	171,46	1,79	1,73	1112,0
Max	171,85	190,75	2,27	2,18	1183,0
Std Deviation	4,60	5,10	0,11	0,11	19,0

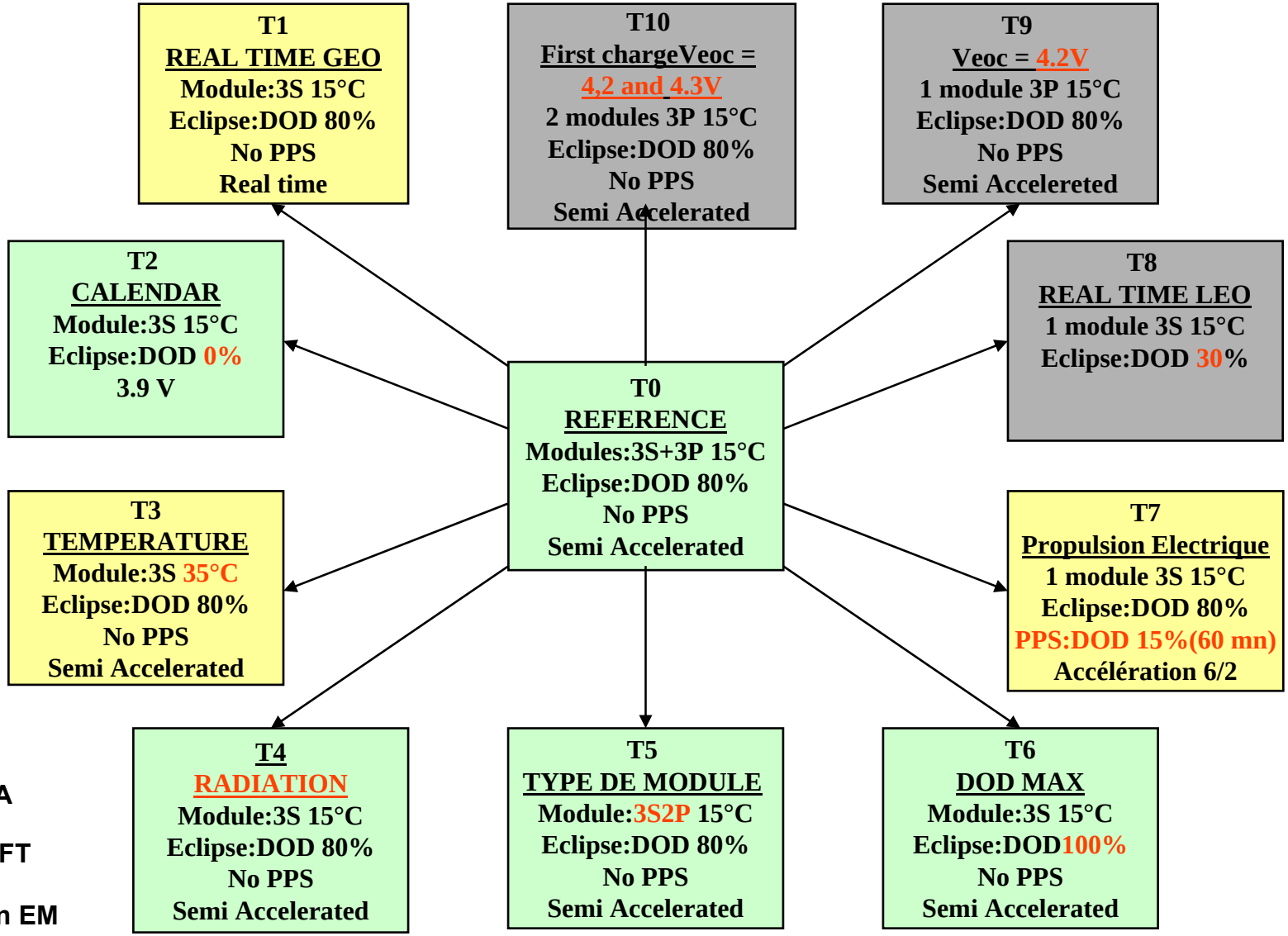
Energy at 4.1V, 20 °C, C/1.5 and weight



Impedance at 20 and 60 % DOD



Life test plan

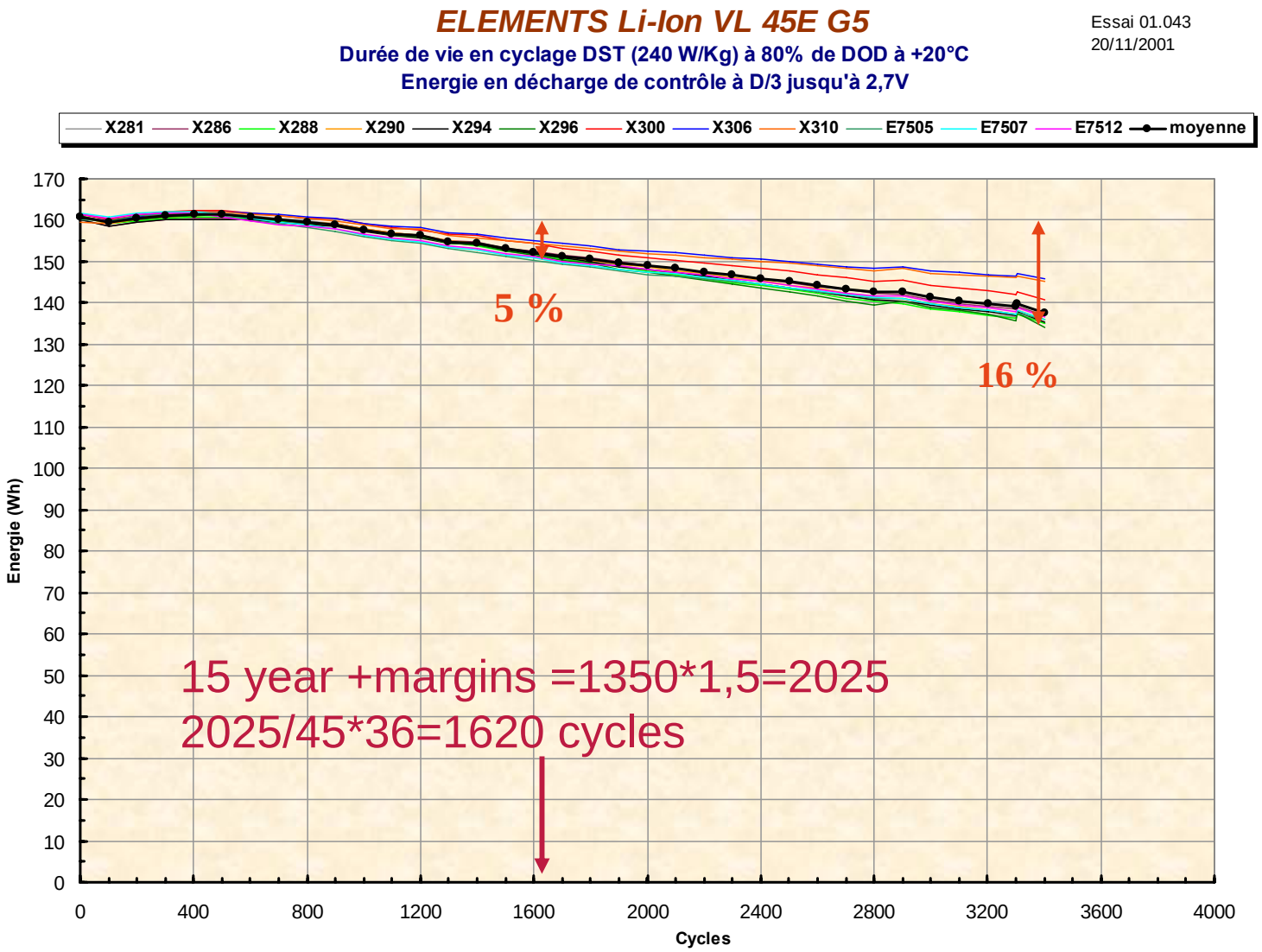


Life test on EV version of VES180

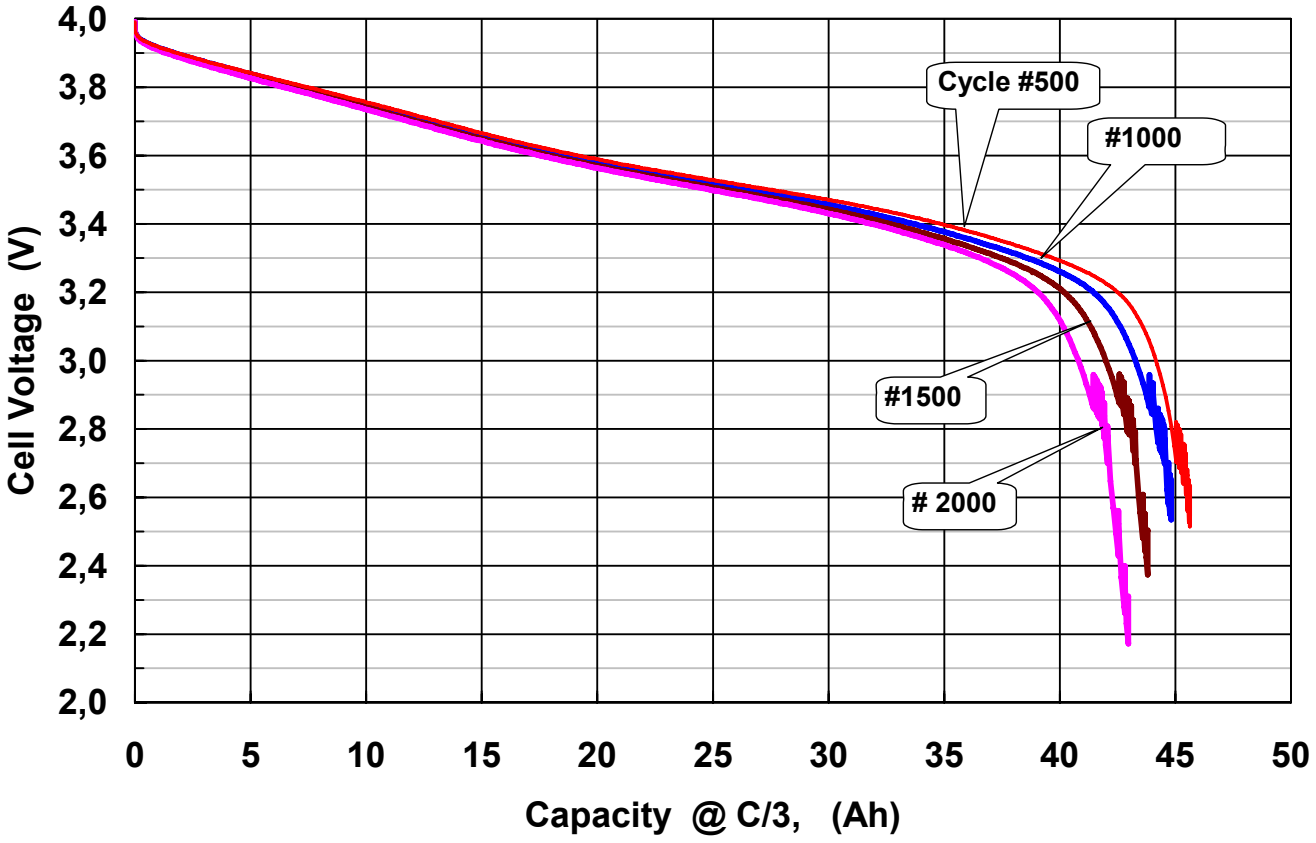
- **On 12 cells :**
  - Constant power discharge 220 W (61 A) @ 80 % DOD
  - EOCV : 4 V
  - Charge time : 4 hours (C/3, C/6 et C/10)
  - Temperature: 20 °C
  - Energy Check every 100 cycles (charge C/5, Discharge C/3)

  - 3 300 cycles done

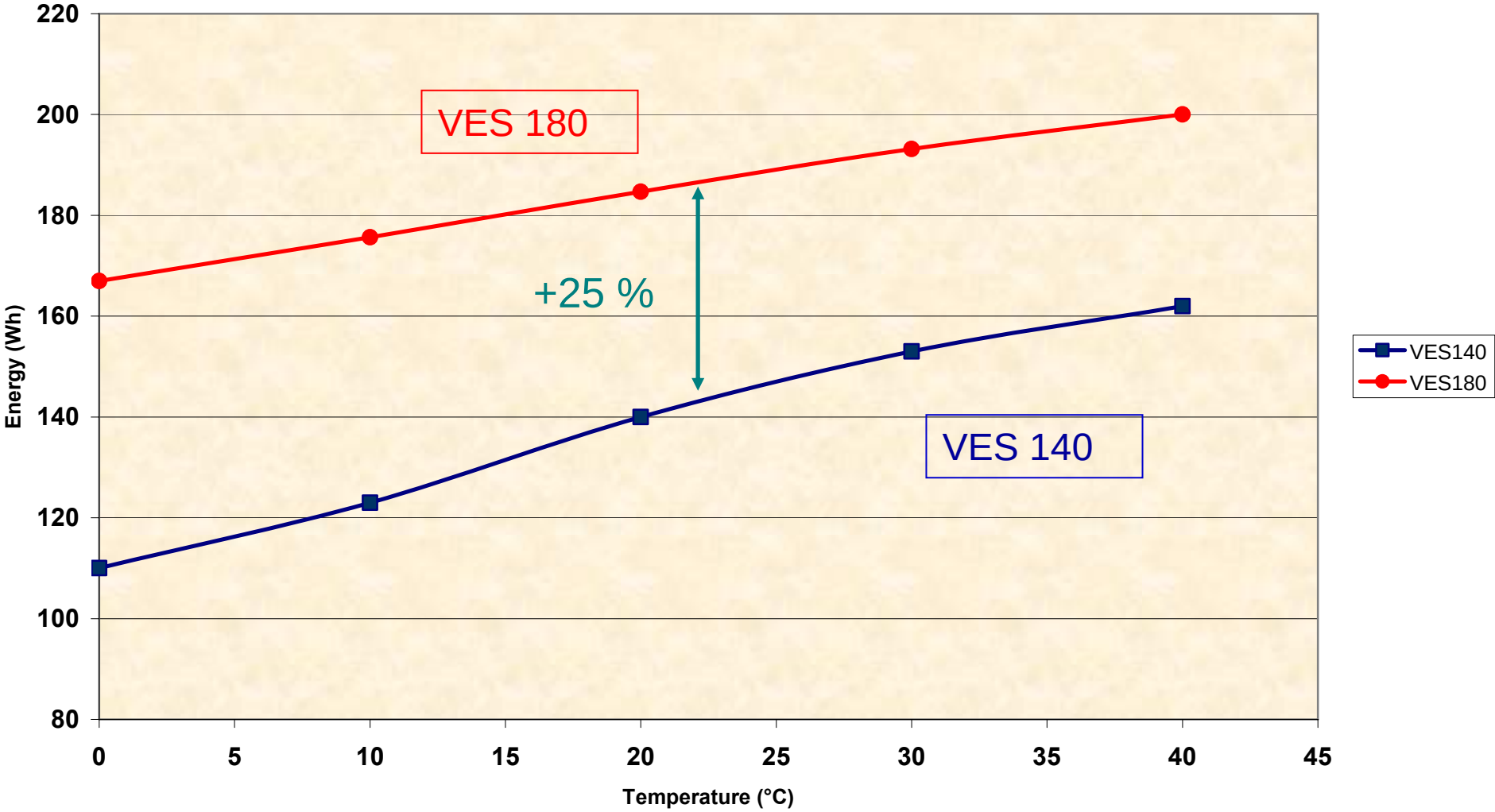
80 % DOD Cycling at 4.0V



Capacity check



Comparison VES140/VES180 : typical values



Conclusion

- **CDR has been held in May 05**
- **First lots (including the qualification lot) have been manufactured**
- **Qualification review is scheduled in Dec 05**
- **Based on first results, the VES180 performances are compliant to the specification with specific energy higher than 170 Wh/kg**
- **VES180 is ready for the Alphabus and Galileosat programs**

Acknowledgments

- **G.Dudley, A.Mauroschat and W.Engels for their technical and financial support on ARTES 8 and life test**
- **B.Castet, P.Tastet for their support on VES180 life test**